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March 2015
EVERYTHING FOR ELECTRONICS

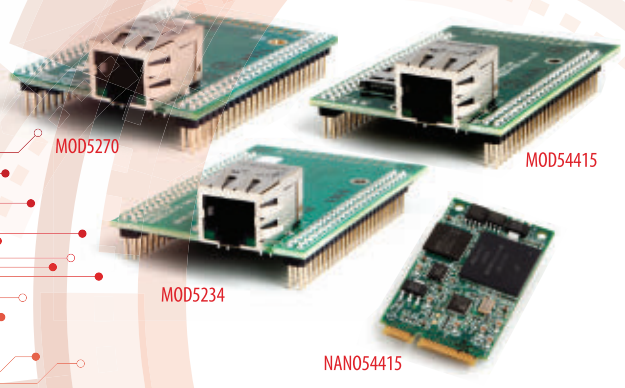
BEYOND THE ARDUINO

Take a look behind the curtain at its AVR brain, and move *beyond the limitations* of the simplified Arduino environment

Sound Amplifier Modules

We bench tested a sampling of some popular choices for this in-depth review. *See how they measured up!*

Ethernet Core Modules with
High-Performance Connectivity Options



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  4 I²C · 3 SPI · 2 CAN · SSI · 6 ADC · 2 DAC · 8 PWM · 1-Wire® interface

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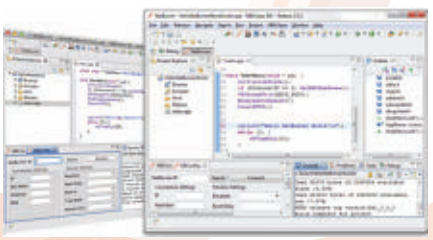

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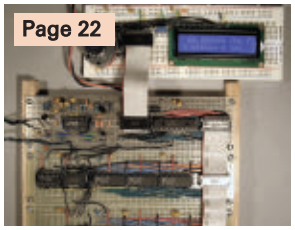

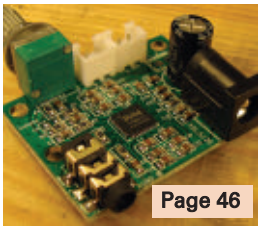

March 2015

22 Build a Frequency Counter
Frequency counters have been around for years as a standard piece of test equipment in both commercial and hobby labs. If you need one for your workshop, take a gander at the one presented here.
■ *By Jim Teixeira*

30 A Cost-Effective Traffic Light Controller
This project spotlights how sometimes the good old fashioned way is the most efficient when constructing circuits.
■ *By Alan Grambo*

36 Beyond the Arduino
Ready to cut the apron strings and discover what it's like to work directly with a microcontroller? This series will help you down that road less travelled.
■ *By Andrew Retallack*

46 Give Your Sound a Boost — Amplifier Modules to Power Your Project's Audio
Want to hear about a way to add sound to your project? Then, check out this review on a selection of low to mid power amplifier modules from Parts Express.
■ *By J.W. Koebel*

54 A Look at the 23rd Annual "Last" Chicago CoCoFEST!
So, what's the big deal about a vintage computer expo in this modern world of Windows, Androids, and iPads? Not only does this event highlight the TRS-80 Color Computer, but it also showcases a unique fusion of old and new technology.
■ *By Salvador Garcia*

Departments

06 DEVELOPING PERSPECTIVES
Starting Out: Avoiding EAD
07 READER FEEDBACK
18 NEW PRODUCTS
20 SHOWCASE
67 ELECTRO-NET
68 NV WEBSTORE
71 CLASSIFIEDS
78 TECH FORUM
81 AD INDEX

Columns

08 Q&A
Reader Questions Answered Here
Find out how to fix burn marks on LCD screens and whether or not to go with CFLs or LEDs.

10 PICAXE Primer
Sharpening Your Tools of Creativity
USB-to-Serial Adapters Revisited.
Explore a hardware solution that allows you to use a wide variety of relatively inexpensive USB-to-serial adapter cables in PICAXE breadboard projects.

59 The Ham's Wireless Workbench
Practical Technology from the Ham World
Oscillators.
Every signal begins with an oscillator — which is a key element in ham radio to generate, mix, and extract the info from these signals. This time, see how to make an audio oscillator, plus learn about common RF types.

64 Open Communication
The Latest in Networking and Wireless Technologies
New Short-Range Wireless Standards Target IoT Applications.
Now, it is easier than ever to connect devices over the Internet with the features available in upgraded versions of Bluetooth and ZigBee.

Page 64

72 The Design Cycle
Advanced Techniques for Design Engineers
A Blueprint for Embedded Wi-Fi.
Last month, we discovered that the Numbat Wi-Fi module on the Moray development board can take care of itself in the wild. However, you can't Wi-Fi in the woods if you have to be attached to the USB port of a laptop. This month, we will replace the USB cable, laptop, and terminal emulator with a simple PIC microcontroller and some tricky CCS C code.

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DEVELOPING PERSPECTIVES

Starting Out: Avoiding the Equipment Acquisition Disorder (EAD)

Starting out in electronics — as with any hobby — requires an investment of time, energy, and finances. This is especially true in the early stages, when unbridled enthusiasm blurs what expenditures on equipment and supplies are necessary and which are detours. It's amazing how easy it is to succumb to the equipment acquisition disorder or EAD — even on a relatively tight budget.

EAD manifests itself in two ways. The first is in the number of pieces of equipment acquired — everything from a digital o'scope to a bench multimeter. The second is in the specifications of each piece of equipment, with a leaning towards an abundance of often unnecessary features.

For example, let's say you start your adventure by setting up a workbench for microcontroller work. At the outset, you'll be faced with determining what equipment is necessary, what's nice to have, and what would simply add clutter to your workspace. If you're like most novices, you'll refer to advertisements, reviews, and perhaps join an online forum or two in hopes of determining exactly what you'll need. Left to your own devices, you might accumulate a dozen different pieces of equipment — either new or used — as your budget allows.

Furthermore, you'll be tempted to lean towards the feature-laden versions of each piece of equipment in the off chance that you might need those extra features one day — even though you're unclear exactly what benefit you'll derive from those features.

For example, let's say you're facing the choice of a $9 wall wart and a $300+ bench power supply. Even though the wall wart will probably be all you need for the first six months or so of your experimentation, you'll be tempted to go for the bench supply. Then, there's the issue of digital readout — number of digits, single readout for voltage and current, or dual digital readouts, current-limiting features, and the like. You could easily end up with a power supply that not only requires more space on your bench, but that is so complex you'll have to spend hours just learning to use every feature. Unless one of your goals is to master commercial power supplies, these are hours that you should have spent working directly with microcontrollers.

How do you avoid EAD? If you're extremely lucky — or persistent — you'll identify a mentor at a local electronics club who will take time to understand you, your plans, and real needs. The second best option is to identify a virtual mentor on one of the many online forums.

The challenge is finding a mentor that doesn't have a hidden agenda linked to sales of equipment or supplies. Otherwise, you could end up with an even more severe case of EAD than if left on your own. I've found that the most credible online mentors emphasize ingenuity over equipment.

Another thing I've learned is that when exploring an unknown field, it's better to learn one thing — be it a device or technique — thoroughly before moving on to something else. Taking this approach will naturally limit any EAD tendencies you might have.

Good luck experimenting. **NV**

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READER FEEDBACK

Electronics Left Out in the Cold

I enjoyed reading Paul Verhage's Near Space column in the May 2014 issue about building an electronic thermometer for a thermal vacuum chamber. The article mentioned that the thermometer could read down to -99 degrees Fahrenheit. My thoughts immediately went to the effects of such cold temperatures on the electronics. (Actually, I guess you have to deal with that factor every time you launch.)

The LM335 temperature sensor, for instance, is rated at -40 degrees Fahrenheit for its absolute maximum rating when operating, and -76 degrees for non-energized storage (I am referencing the Texas Instrument's datasheet). I would think that many of the other components on your board would be similarly rated by their manufacturers.

My limited electronics knowledge is self-taught. I always looked upon the ratings in a datasheet as being definite, but it appears from your project that the ratings are not absolute. Could you please say a few words on the subject, and about your own experience with component reliability in the face of such cold temperatures? Thank you!

Judy May W1ORO
Union, KY

Thanks for asking, Judy. It's great to get letters from readers.

Actually, my thermometer for the TVC works to -99 degrees because that's the lowest temperature the

Continued on page 45

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Our 38th Year

In this column, Tim answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com.**

- **Burn Marks on LCD Screen**
- **CFLs vs. LEDs for Residential Lighting**
- **Mailbag**

Post comments on this article at **www.nutsvolts.com/index.php?/magazine/article/march2015_QA.**

Burn Marks on LCD TV Screen

Q Is there anything I can do about burn marks on an LCD television? Thanks.

— Mark Erickson, El Paso, TX

A I'm assuming that your problem is image persistence which exhibits a "ghost" type reflection which remains on the screen when the on-screen scene is changed. Image persistence is usually caused by viewing a static screen for long periods of time. What happens is the LCD pixel element crystals become "locked" in a certain state due to staying in this position for prolonged periods of time.

First, check the manufacturer's information to see if the set has a built-in fix for image persistence. I am assuming that you have already tried turning the TV off for 24 to 48 hours to see if the problem will clear itself.

A simple fix that I would try first is to reduce the brightness and contrast settings for the TV screen. If this doesn't work, try running the set with a "snow" pattern by tuning to a channel that does not have a signal (some devices produce a blue screen when no signal is present, so this step will not work). If the image retention persists (pun intended), you may want to buy a screen maintenance tool such as Pixel Protector (**www.pixelprotector.com**). Some of our readers may have other solutions they can submit.

Let me know how these ideas work out.

Residential Lighting: CFL Versus LED

Q I am looking for ways to save energy and protect the environment, so I was wondering which lamps are better for home lighting: CFLs or LEDs?

— Charles Davis, Portsmouth, VA

A Saving energy and protecting the earth's environment should be goals that everyone is seeking to achieve. Until the past decade, most residential lighting was provided by the incandescent or tubular fluorescent lamps. Historically, anything that would burn — such as tar, plant materials, olive oil, whale oil, kerosene, etc. — was used until a reliable incandescent bulb was commercialized in the late 1800s by Thomas Edison *et al*. Fluorescent lighting was commercialized in the late 1920s.

Tungsten filaments in the incandescent lamps are heated via electrical current flowing through the resistance of the filament. This generates heat, thus causing the filament to emit visible light and heat. The heat of the incandescent bulb is wasted in most cases since it does not provide any visible light, yet constitutes about 85 to 95% of the energy input to the bulb. (On the plus side, I have used incandescent bulbs to heat an outdoor animal hutch in the winter for which they were very effective.) The fluorescent tube lamps waste around 70% of the electrical energy they receive, so they reduce energy consumption tremendously as compared to incandescent

MAILBAG

Re: Dec 2014; page 14; Need Battery Monitor Circuit:

The IC you mentioned (MN13811-M) is not available online, or at least I can't find it. This is a nice little project but if the parts are not available to the public, then what is the point of publishing it in the first place?

Pete Emmel via email

Thank you, Pete for catching my major blunder. Upon further research, I found that the MN13811-M used in the ***www.circuitstoday.com*** *battery monitor circuit is no longer stocked (I looked up the tech specs but failed to see the word "discontinued"). Further research found the NCP301LSN31T1G has a 3.1V reset voltage/open drain N-channel active high device like the MN13811-M (both devices generate a high output when the input voltage drops to the reset value), except the NCP301LSN31T1G is available (at least as I type this answer as surface mount instead of thru hole) from the manufacturer, ON Semiconductors in sample sizes or tape and reel (****www.onsemi.com/PowerSolutions/product.do?id=NCP301****). Mouser Electronics also has this part available* ***www.mouser.com/ProductDetail/ON-Semiconductor/NCP301LSN31T1G/?qs=%2FugrpAKHX8qlQVgDtV2w2g%3D%3D****). If you need a 3.2V reset voltage, use the NCP301LSN32T1G. It has five terminals (versus three for the MN13811-M's TO-92 package) but only three are used, with the other two helping secure the chip to the circuit board.*

You can see the datasheet for the NCP301LSN31T1G at ***www.onsemi.com/pub/Collateral/NCP300-D.PDF****.*

I'll repeat myself again: I don't know everything and I rely on our sharp-eyed readers to keep me straight. I'll try to do better in the future. Tim Brown

lamps. Compact Fluorescent Lamps (CFLs) waste about 25% of the energy input, and Light Emitting Diodes (LEDs) waste only about 10 of the input energy, so the reduction of electrical power usage is even greater using CFLs or LEDs rather than incandescent bulbs or fluorescent tubes. Since the electrical power used to light a home is approximately 25%, the reduction in wasted energy pays environmental dividends by creating a smaller "carbon footprint" (close to 70% of electricity in the US is produced by petroleum, coal, or natural gas which generate carbon dioxide — a major greenhouse gas). CFLs and LEDs are manufactured so they can be installed in the same ubiquitous fixtures as incandescent bulbs, which explains their popularity.

However, there are caveats: (1) Incandescent lighting fixtures are relatively cheap and reliable; (2) Fluorescent tube fixtures use ballasts (auto-transformers) that fail a lot more often than the incandescent fixtures; (3) CFLs and fluorescent tube lamps contain mercury which is an extremely toxic material, so their disposal is an environmental hazard as is the non-biodegradable glass and the slightly toxic Tungsten in incandescents.

CFLs are much more expensive than incandescent bulbs, and LEDs are more expensive than CFLs. LEDs contain arsenic, lead, and several other hazardous metals. (Hey, nobody is perfect. I feel that the pollutants in LEDs are easier to deal with than the glass and mercury in fluorescents or the glass and Tungsten in incandescents.)

My personal experience comes from re-lamping most of our residential incandescent fixtures with CFLs. The energy savings was enough that — after the first two years — the power company owed me money at the end of the year, plus reduced my Equal Payment Plan fee the next year.

I have noticed than the cheaper CFLs do not last as long as I would like, but their life still exceeds that of incandescents and the savings goal is still achieved. My experience with LEDs consists of several flashlights I bought because they used LEDs. I give the LEDs a glowing (pun intended) review: longer bulb life; not susceptible to destruction when you drop the flashlight (I have destroyed many incandescent bulbs this way); the small size of the LED flashlight gives much more light than some of my larger sized incandescent lights; and the batteries seem to last forever (months vs. a couple of weeks in the incandescent lights). All in all, looking at bulb cost, longevity, power consumption, and environmental considerations, I feel that the LEDs are the way to go. **NV**

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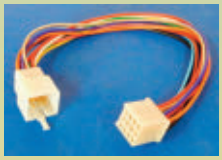
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■ BY RON HACKETT
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USB-to-Serial Adapters Revisited

Back in the June 2010 installment of the Primer, we discussed the FTDI USB-to-TTL serial cable, and how a single cable can be used to both power and program a PICAXE breadboard circuit. The FTDI cable is simple to use, plus it consumes much less breadboard space than the standard AXE027 programming cable and a separate power supply. As a result, I almost always choose the FTDI cable whenever I'm setting up a new PICAXE breadboard project.

Unfortunately, the FTDI cable has a downside. Even though it's cheaper than the AXE027, it's still relatively expensive — especially if you want to work on more than one project at the same time.

I originally chose to use the FTDI cable because it was the only cable that I could find that included the capability of inverting the polarity of the TxD and RxD signals in software, which is necessary for the PICAXE programming interface. As far as I know, that's still the case.

However, this month, we're going to explore a hardware solution to inverting the TxD and RxD signals so that a wide variety of relatively inexpensive USB-to-serial adapter cables can be used for our PICAXE breadboard projects.

In the process of writing this month's column, I experimented with a couple of different logic gates (inverters and NAND gates). A logic gate can certainly be used to invert a data signal, but it turns out that the most space-efficient solution (at least for non-SMD parts) is to simply use an NPN bipolar transistor for this purpose. I chose the 2N3904 NPN, but any general-purpose NPN transistor should do.

Experiment 1: Using an NPN Transistor as a Data Inverter

Figure 1 shows the schematic of a simple NPN data inverter. The schematic doesn't show the standard PICAXE programming circuit, but, of course, you need to include one — just use whatever programming connection you prefer.

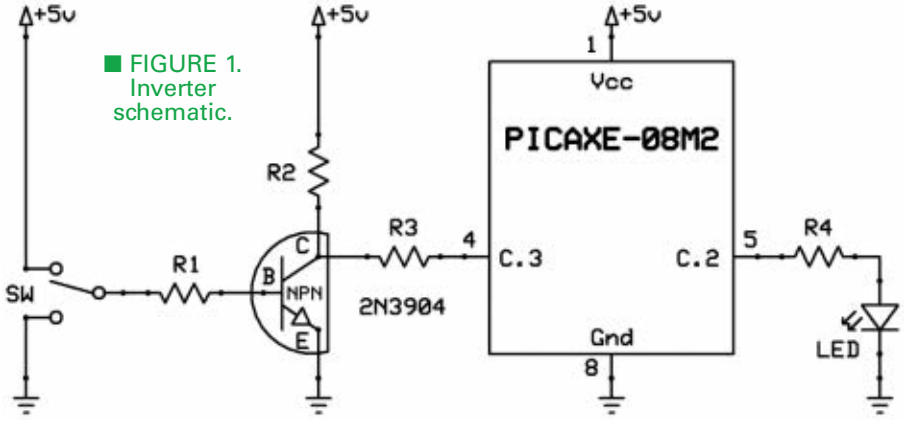
The circuit in **Figure 1** may look familiar. That's because we've already used an NPN transistor as a switch back in our first LED-multiplexing project way back in the December 2009 *Nuts & Volts*. Since that's quite some time ago, let's quickly review the basics of transistor switches.

First, as you may remember, the three junctions of a bipolar transistor are referred to as the base, the collector, and the emitter. (In **Figure 1**, they are labeled "B," "C," and "E," respectively.) Second, the standard symbol for an NPN transistor includes a small triangle pointing away from the base at the emitter connection.

Third, when using an NPN (or PNP) transistor as a switch, the general rule is that the switch will turn on (i.e., current will flow from the collector to the emitter) whenever the base is "taken toward" the collector, i.e., whenever the base is connected to the same voltage level as the collector.

Finally, the transistor is not a "perfect" switch. In other words, there's a small internal voltage drop between the collector and the emitter whenever the transistor switch is "on." For my setup, I measured the drop to be about 0.3V.

In order to understand how the transistor switch in **Figure 1** functions



■ FIGURE 1. Inverter schematic.

as an inverter, let's examine the two possibilities.

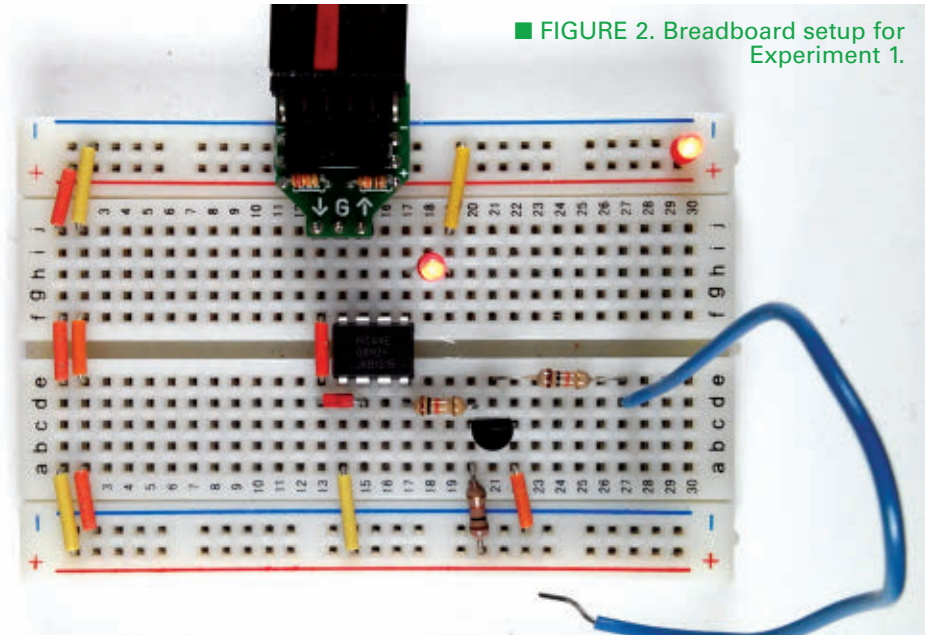
The collector is tied to +5V through R2, which serves as a current-limiting resistor. Therefore, when the base of the transistor is also connected to +5V (through R1, which is a current-limiting resistor too), the transistor "turns on" which effectively connects the collector to ground. However, don't forget the small internal voltage drop I mentioned earlier.

As a result, it would be more accurate to say that the collector is connected to 0.3V, not 0.0V (ground), but that voltage drop isn't significant, and it's simpler to just think of it as "the collector is connected to ground." On the other hand, when the base of the transistor is connected to ground, the transistor "turns off," which disconnects the collector from the emitter (i.e., no current can flow into the collector). So, in **Figure 1**, the collector is simply connected to +5V (through its current-limiting resistor).

To summarize the above: When the base of the NPN transistor is at +5V, the collector is (almost) at ground; when the base is at ground, the collector is at +5V. In other words, the transistor switch functions as an inverter: high in = low out, and low in = high out.

Now, let's turn our attention to the level of the input signal at pin C.3 of the 08M2. The first point that needs clarification is resistor R3 — which is connected between the collector of the 2N3904 and pin C.3 on the 08M2. As you know, pin C.3 on the 08M2 is fixed as an input. As a result, R3 is really not needed at all.

If we were to replace it with a jumper wire, the circuit would still function properly. Whenever the 2N3904 collector is at a high level, the input to pin C.3 is at a high level; whenever the 2N3904 collector is at a low level, the input to pin C.3 is at a low level. However, consider what would happen if we accidentally connected the collector to pin C.4 rather than pin C.3.



■ FIGURE 2. Breadboard setup for Experiment 1.

If C.4 happened to be configured as an output, whenever the voltage level at the collector differed from the voltage level on the C.4 output, a direct short would occur, and the transistor and/or the 08M2 would probably be damaged. Resistor R3 prevents that from happening by limiting the current flow to a safe level.

At first glance, it might appear that resistors R2 and R3 form a voltage divider, but that's not the case. As we discussed earlier, when the voltage at the base of the transistor is +5V, the transistor switch turns on, so the collector is connected to ground and pin C.3 is pulled low through R3.

On the other hand, when the voltage at the base of the transistor is 0V, the transistor switch turns off, so no current flows through the collector and pin C.3 is held high through the combined resistance of R2 and R3.

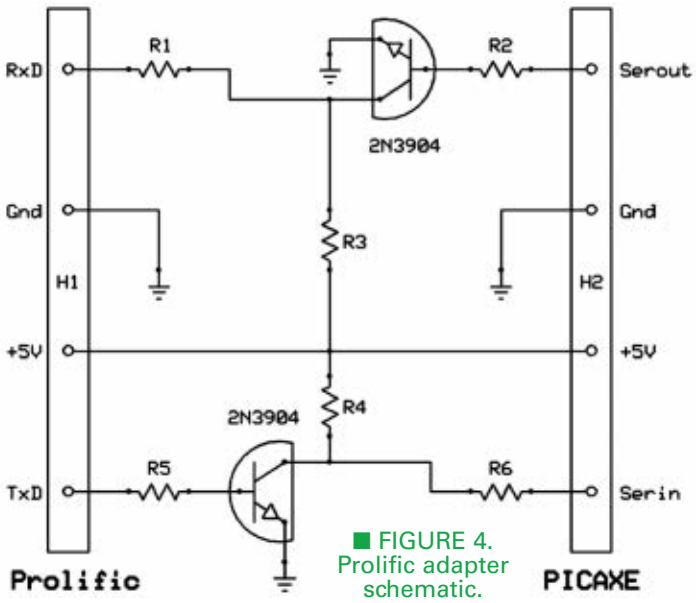
Before actually testing our inverter circuit, there's one last point I want to mention. The only reason the 08M2 is included in the circuit is to provide visual feedback for the state of the pin C.3 input. The program to accomplish this goal is really simple, as we will see when we've completed construction of the test circuit.

However, if you prefer, you can eliminate the 08M2 altogether, and simply use a multimeter to measure the voltage at the right end of R3 as you change the voltage level that's input to the base of the transistor.

At this point, we're finally ready to test our simple inverter circuit. A formal parts list isn't really necessary; all you need is a 2N3904 transistor (or any general-purpose NPN transistor you have on hand), three current-limiting resistors (I used three 10K resistors, but anything between 1K and 10K will also work), a resistorized LED (or a regular LED and a current-limiting resistor), and an 08M2 processor with a programming circuit. If you're missing anything, all the necessary parts (except the 08M2) are available on my website.

Figure 2 shows my completed breadboard setup for this experiment. As you can see, I deviated from the schematic in two minor ways: I'm using a resistorized LED (so I omitted R4), and I replaced the SPDT switch with a long jumper wire (which you can see dangling in the lower right corner of the photo). (When we run the experiment, we'll just insert the

■ FIGURE 3. Pinout of the PL2303HX cable.



■ FIGURE 4. Prolific adapter schematic.

unconnected end of the jumper wire into either the +5V rail or the ground rail.) The jumper wire provides an opportunity to observe an interesting aspect of the circuit, as we'll soon see.

When you've completed your breadboard setup for the experiment, we can turn our attention to the program we'll use to test the inverter. It's so short that I'm including it here; just type it into the PICAXE Editor. The program simply displays the real time state of the input to pin C.3 on the LED. If the input is high, the LED is on; if the input is low, the LED is off.

```
' === InverterTest.bas ========
' Program tests the 2N3904
' inverter.

' === Directives ========
  #com 6
  #picaxe 08M2
  #terminal off
  #no_data

' === Constants =========
  symbol      LED = C.2

' === Variables =========
  symbol data_In = pinC.3

' === Begin Main Program ======
do
  if data_In = 1 then
    high LED
  else
    low LED
  endif
loop
```

After you type this code into the PICAXE Editor, download it to your breadboard setup. Whenever you insert the loose end of the long jumper wire into the +5V rail, the LED should be off; whenever the loose end of the jumper wire is inserted into the ground rail, the LED should be on.

Also, note what happens whenever you disconnect the jumper wire from the +5V rail — the LED immediately lights. In other words, +5V is the **only** input level that results in a low input to pin C.3. If the input to the transistor switch is at ground level or if it is entirely disconnected, the input to pin C.3 is high.

When you're finished testing your breadboard setup, we can move on to applying what we've learned in Experiment 1. We're going to invert the Tx and Rx data signals on a USB-to-serial cable, so that it can be used to power and program our PICAXE projects.

Experiment 2: Inverting the Data Signals on a USB-to-Serial Cable

I chose to use the Prolific PL2303HX cable for Experiment 2 because it's known to work reliably with PICAXE processors (as long as the two data signals are inverted — which we're about to do); it's readily available; and it sells for less than half the price of the FTDI cable.

Figure 3 presents the pinout of the cable that we'll be using in this experiment. A cable with the same color-coding is available on my website (**www.JRHackett.net**) and elsewhere. (If you use a different PL2303HX cable, the color coding of the four wires may differ.)

The schematic for Experiment 2 (and 3) is presented in **Figure 4**. Essentially, it consists of two NPN transistor inverter circuits: one for each of the two data signals. Both inverter circuits function identically to the single inverter circuit of Experiment 1, and all six current-limiting resistors are again 10K.

In this experiment, we can ignore the two headers in the schematic and just focus on the required connections. (When we get to Experiment 3, we'll discuss the two headers.) As you can see in **Figure 4**, the output signal from the Prolific TxD line is connected to the base of the lower inverter, and the inverted output of the lower transistor is fed to the *Serin* input on a PICAXE

processor; the output signal from the PICAXE *Serout* line is connected to the base of the upper inverter, and the inverted output of that transistor is fed to the RxD input on the Prolific cable.

Figure 5 shows my completed breadboard setup for this experiment. Before assembling your own breadboard circuit, take some time to trace the wiring on my breadboard, and make sure you understand how it implements the circuit of **Figure 4**. Also, note the resistorized LED that's connected between the 08M2 *Serout* line and ground. We're going to test the Prolific USB-to-serial programming interface by downloading a simple "Hello World!" program that blinks the LED on the *Serout* line (i.e., pin C.0).

Also note that there's no switch in the power connection from the Prolific cable; in order to turn off the power to the breadboard, it's necessary to disconnect the cable. (We'll return to that point before we're finished this month.)

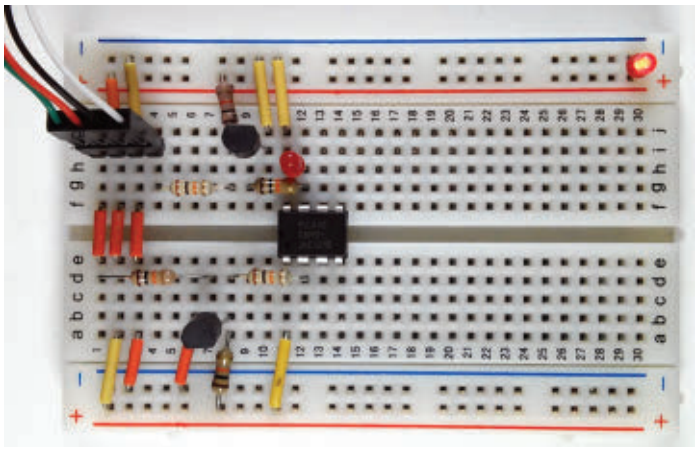
When you've completed your breadboard setup for the experiment, we're ready to look at the software we'll use to test the programming circuit. (Actually, the real test of the circuit is to see whether it downloads the program to the 08M2.) As in Experiment 1, our test program is really simple, so just type it into the PICAXE Editor.

As I mentioned above, the program just blinks the LED on pin C.0 to say "Hello world!"

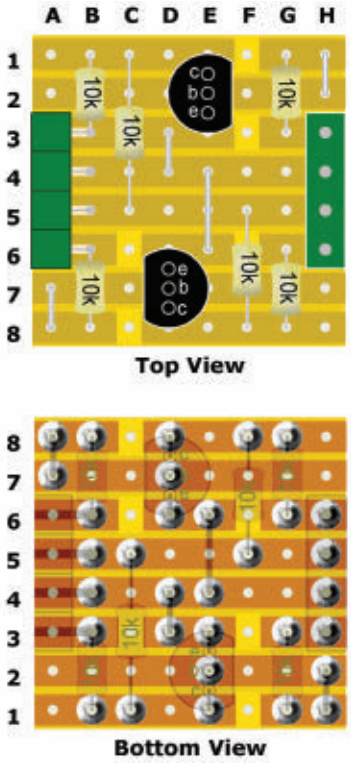
```
' === ProlificTest.bas =====
' Program tests the Prolific
' programming connection.

' === Directives ===
  #com 6
  #picaxe 08M2
  #no_data
  #terminal off

' === Constants ====
  symbol abit = 500
  symbol  LED = C.0
```



■ FIGURE 5. Breadboard setup for Experiments 2 and 3.



■ FIGURE 6. Prolific adapter layout.

```
' === Begin Main ===========
do
  high LED
  pause abit
  low LED
  pause abit
loop
```

Type the program into the PICAXE Editor and download it to your breadboard setup. You should see the LED blinking about once per second; if not, you will need to troubleshoot your breadboard wiring.

Experiment 3: Constructing a Stripboard Programming Adapter

If you're interested in using a Prolific USB-to-serial adapter cable to power and program your PICAXE breadboard circuits, you would certainly want a more convenient solution than the breadboard circuit we just tested. Of course, the obvious solution is to construct a stripboard version of the circuit, and that's just what we're going to do now.

Figure 6 shows the stripboard layout for our USB-to-serial inverter. (A large size version of the layout is available for downloading at the article link.) The schematic for this circuit is identical to the one presented earlier in **Figure 4**. In that schematic, H1 is the four-pin right angle male header on the left side of the stripboard layout, and H2 is the four-pin female header on the right side of the layout. If you're interested in constructing the stripboard version of our USB-to-serial inverter project, you may want to start by tracing the wiring in **Figure 6** to make sure you understand how it also implements the schematic of **Figure 4**. The Parts List for the stripboard circuit is shown in **Figure 7**. Again, all the necessary parts (including the Prolific PL2303HX cable) are available on my website and elsewhere, but you may already have most of the parts on hand.

Prolific PL2303HX USB to Serial Cable
Transistor, 2N3904, TO-92 (2 pcs.)
Resistor, 10k, 1/6W (6 pcs.)
Header, Female, Straight, 4-pin
Header Male, Right Angle, 4-pin

■ FIGURE 7. Parts List for Prolific adapter.

The construction of the stripboard circuit is very straightforward, so a list of instructions isn't necessary. As usual, install the parts by starting with the lowest ones (the jumper wires), and work your way up to the tallest (the four-pin female header). However, there is one point that I should mention: The holes at B3 and B6 need to be slightly enlarged so that a header pin and a resistor lead will fit in the same hole.

A 1/16 inch drill bit is large enough — just be sure to drill the board with the traces facing up so you don't tear out the traces around the holes.

If you prefer not to take this extra step, just cut the stripboard so that the traces include nine holes rather than eight, and move the four-pin right angle male header one position to the left.

When you've completed construction of the stripboard circuit, you can test it with the same program that we used in Experiment 2.

Figure 8 is a photo of my completed stripboard circuit, and **Figure 9** shows how I connected it to my breadboard circuit. As you can see, I used a second stripboard to make the connection. This approach makes it easier to make the +5V and ground connections to the power rails with two jumpers (that aren't visible) underneath the joining stripboard. However, you can just use four jumper wires to make the necessary connections if you prefer.

Our USB-to-serial inverter circuit provides a simple and inexpensive way to power and program our PICAXE breadboard circuits with a single connection. If your primary computer is a laptop, it also enables the possibility of mobile project development. (I've actually worked on the hardware portion of PICAXE projects while commuting on the local railroad!)

Before wrapping up Experiment 3, there's one final point that needs to be mentioned. If you use the inverted Prolific cable to develop a PICAXE project that will ultimately be powered by batteries (or any other power source), don't forget that if you remove the USB cable and inverter board from your circuit, you will need to tie the processor's *Serin* pin to ground (via a 100K resistor) in order for the circuit to function correctly.

Of course, the same thing is true for the AXE027, the FTDI cable, or any other programming connection.

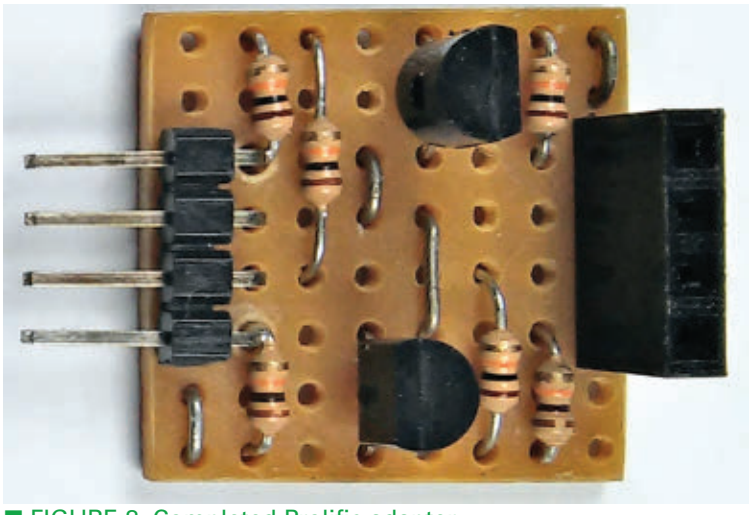
Where's the Power Switch?

As I mentioned earlier, there's no power switch on the USB-to-serial inverter board; to disconnect power from the breadboard, you have to physically disconnect the cable. I'm sure you're wondering why, so let me explain.

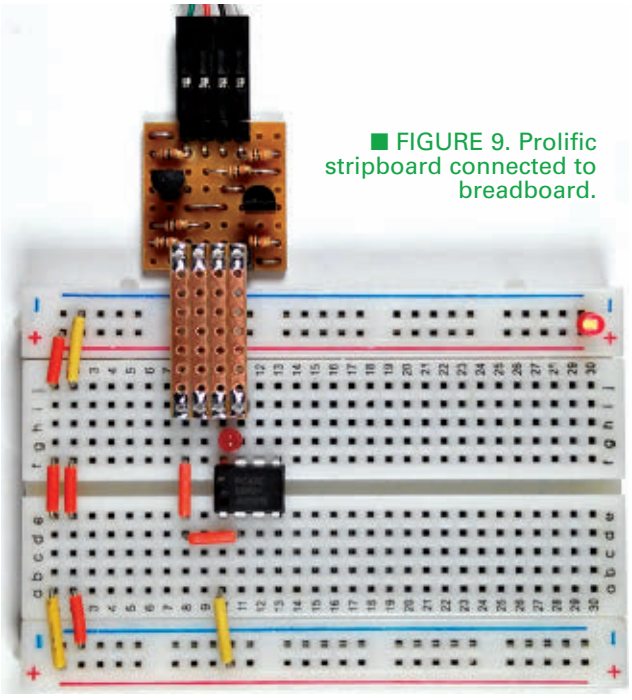
The inverter board is part of a larger project that I've been working on recently. Back in the June 2010 Primer, I introduced the FTDI-based AxMate programming adapter, and for some time now, I've wanted to extend the AxMate concept so that it can work with a variety of USB-to-serial adapters.

Since all PICAXE processors require the serial programming data to be inverted, and (as far as I know) the FTDI cable is the only adapter that supports software inversion of the data lines, I decided to develop a two-board system which includes an adapter board containing the circuitry required by a specific USB-to-serial cable (e.g., FTDI, Prolific, AXE027), and an interface board containing the circuitry required by all USB-to-serial cables (i.e., a switch, an LED power indicator, and a by-pass capacitor).

So far, I've developed three different adapter boards:

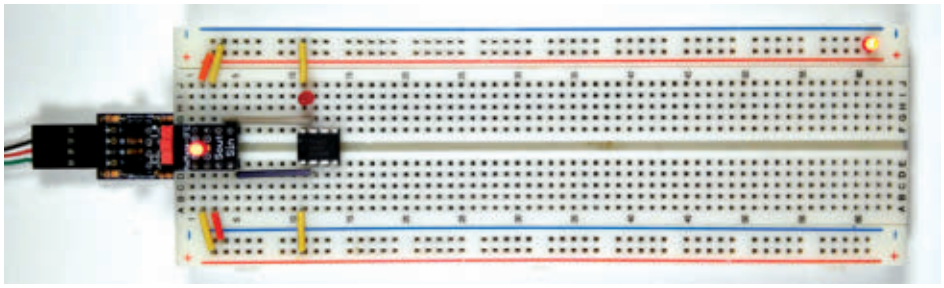


■ FIGURE 8. Completed Prolific adapter.



■ FIGURE 9. Prolific stripboard connected to breadboard.

- **FTDI-IFB** contains the necessary current-limiting resistors for a software-inverted FTDI cable.
- **Prolific-IFB** includes the inverting circuitry we just developed.
- **Stereo-IFB** contains a female stereo connector and the standard PICAXE programming circuitry.



■ FIGURE 10. AxMate-IFE and Prolific-IFB on large breadboard.

Each of the above adapter boards includes a 4x2 female header with the same pinout that we just implemented on the Prolific stripboard circuit, except that there are two rows of pins rather than one.

The female header mates with a 4x2 male header on the AxMate interface board that includes the circuitry I mentioned earlier. I chose to use two-row headers because I want to have the option of connecting an eight-wire ribbon cable to the AxMate board for possible future projects.

Similarly to the original AxMate boards, there are two versions of the new AxMate board: the **AxMate-IFS**, which can be inserted along the side of a standard small (300 hole) breadboard; and the **AxMate-IFE**, which can be inserted at one end of a standard small breadboard.

As I was writing this article, I realized that the AxMate-IFE board can also be used with a large (630-hole) breadboard (see **Figure 10**).

Of course, the AxMate-IFS doesn't have the same flexibility because the holes in the power rails and the main portion of the breadboard are aligned differently the on small and large versions.

However, it would be easy to design an AxMate-IFS board for use

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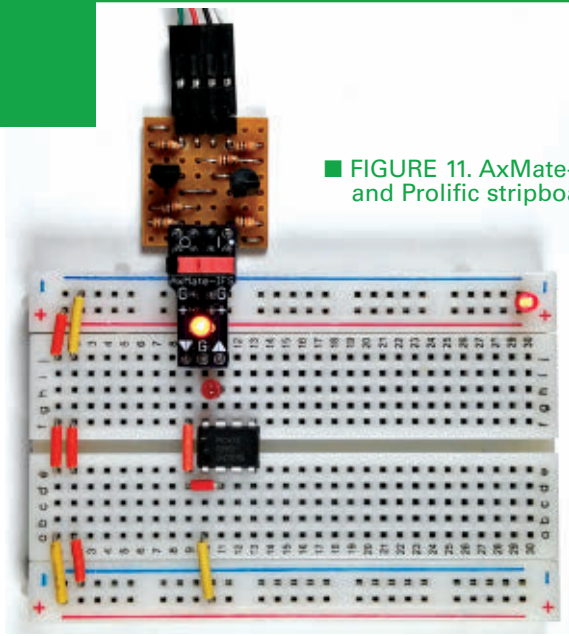
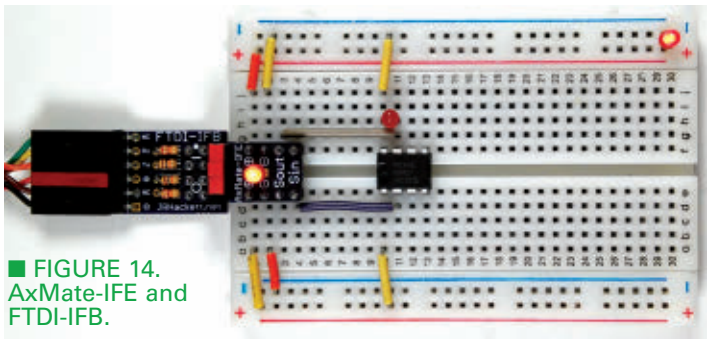
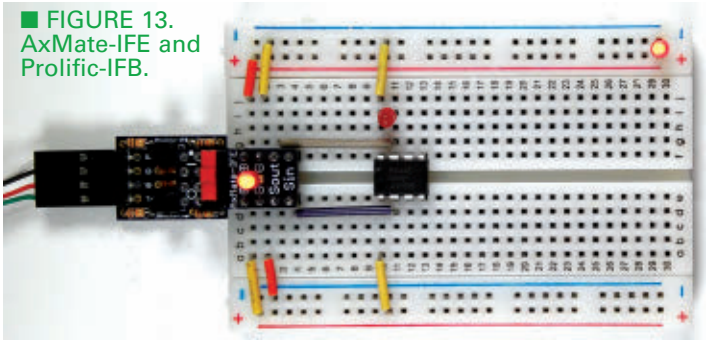


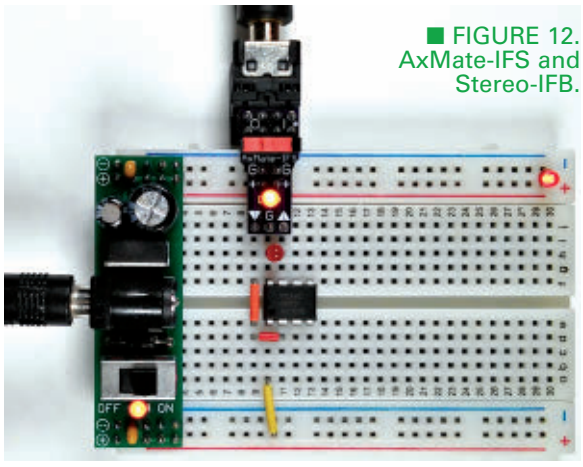
■ FIGURE 11. AxMate-IFS and Prolific stripboard.



■ FIGURE 14. AxMate-IFE and FTDI-IFB.



■ FIGURE 13. AxMate-IFE and Prolific-IFB.



■ FIGURE 12. AxMate-IFS and Stereo-IFB.

with large breadboards, so I think I'll add that to my to-do list.

Each of the three adapter boards (FTDI, Prolific, and Stereo) can be mated with either the AxMate-IFS or the AxMate-IFE board, which provides a good amount of flexibility in PICAXE programming setups.

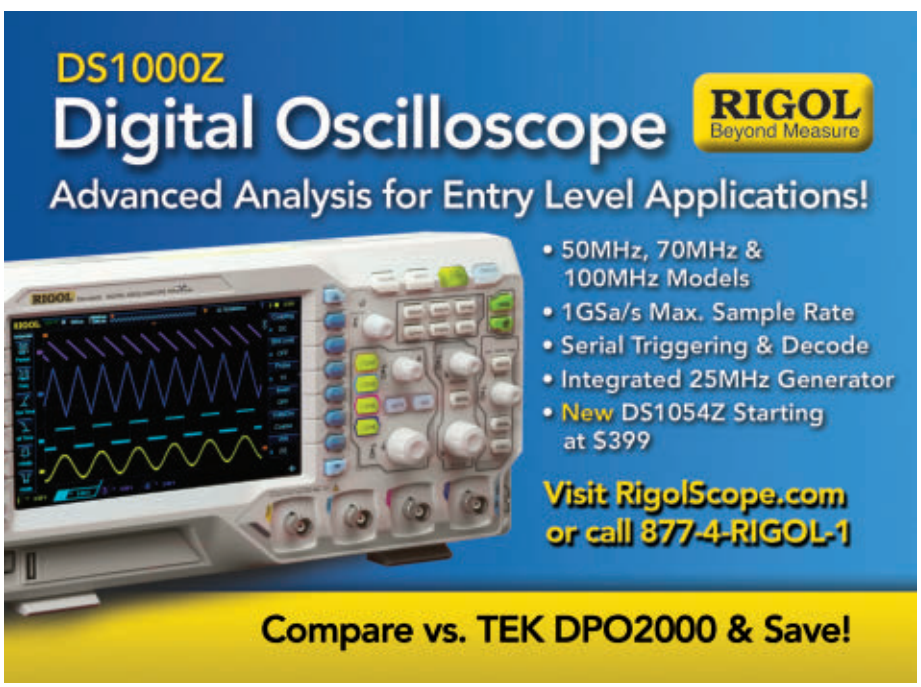
The following figures present a few of the possibilities:

- **Figure 11:** AxMate-IFS and Prolific stripboard adapter.
- **Figure 12:** AxMate-IFS and Stereo-IFB.
- **Figure 13:** AxMate-IFE and Prolific-IFB.
- **Figure 14:** AxMate-IFE and FTDI-IFB.

As you can see in these figures, dividing the PICAXE programming interface circuitry between the two sets of boards provides the flexibility of a "mix and match" approach to powering and programming PICAXE breadboard circuits.

This is especially true in situations where we need to connect more than one USB-to-serial adapter cable to the same PICAXE project — which is exactly what we're going to do with our Prolific cable in the next installment.

See you then ... **NV**



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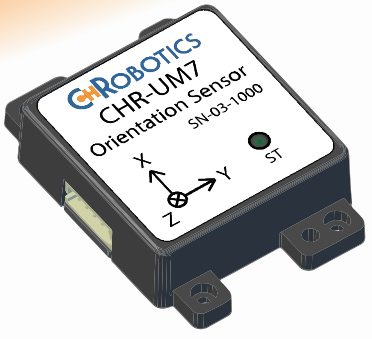

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In addition to the new LED vintage light bulbs, Super Bright LEDs also offers a selection of LED globe bulbs, LED bi-pin bulbs, LED tube lights, LED smart bulbs, LED strip and tape lights, LED panel lights, and LED T8 tubes.

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Web: **www.superbrightleds.com**

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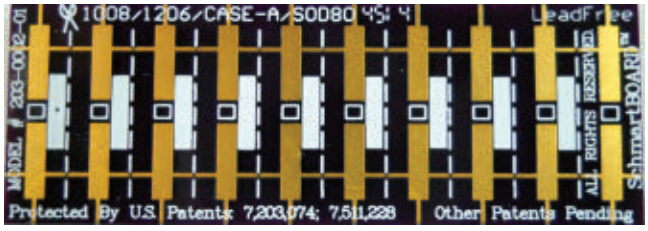
SchmartPatch — new from SchmartBoard — allows users to add surface-mount components to a substrate such as a printed circuit board (PCB), or to replace existing components.



SchmartPatch boards each support multiple pre-defined components and allow one to cut off a pad from the SchmartPatch (using scissors or a blade), stick the pad on to the surface of the substrate (utilizing adhesive already on the back of the SchmartPatch), and then solder a component onto the SchmartPatch.

The component pads are routed to other pads that allow one to solder jumper wires from the SchmartPatch to make the electrical connection to the substrate.

SchmartBoard sees a few scenarios that the product can be utilized for. One situation might be to replace ruined pads in a circuit board repair in the field. Another example might be to add a component to a run of PCBs to resolve an issue immediately rather than waiting for new PCBs to arrive. They can also be used as part of one's prototyping or project development.

SchmartBoard has released six types of SchmartPatch boards. Each comes in packs of four for a retail price of $15. Volume purchases can be arranged with SchmartBoard directly for larger rework needs.

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Anaren, Inc.'s, Wireless Group has announced the release of its first AIR for WICED™Smart Bluetooth module and Atmosphere on-line developer platform as part of a strategic engagement with Broadcom Corporation. This new relationship advances the goal of both companies to support designers, innovators, and end-equipment manufacturers looking for intuitive, easy-to-use developer tools (like Atmosphere) that will simplify the challenge of 'going wireless' and speed up their time to market. In beta trials of its new module and Atmosphere tool, customers were able to get their product "proof of concept" running in 90 minutes or less.

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Measurement Computing Corporation has announced the release of the E-1608: an Ethernet-based multifunction Data Acquisition (DAQ) device. The E-1608 provides both analog and digital I/O, and is priced at $499.

The E-1608 features 250 kS/sec sampling and 16-bit resolution. It offers eight analog inputs, eight digital I/O, one counter input, and two analog outputs. The device is supported in Windows and Android operating systems; Linux support will be added in the near future. An OEM board-only version is also available.

Microsoft Windows software options for the E-1608 include DAQami and TracerDAQ® to display and log data, along with comprehensive support for C, C++, C#, Visual Basic, and Visual Basic .NET. Drivers for DASYLab and NI LabVIEW are also provided.

Android support for the E-1608 allows users to develop DAQ applications for tablets and smartphones. Free sample applications are available for download on Google Play™.

For more information, contact:
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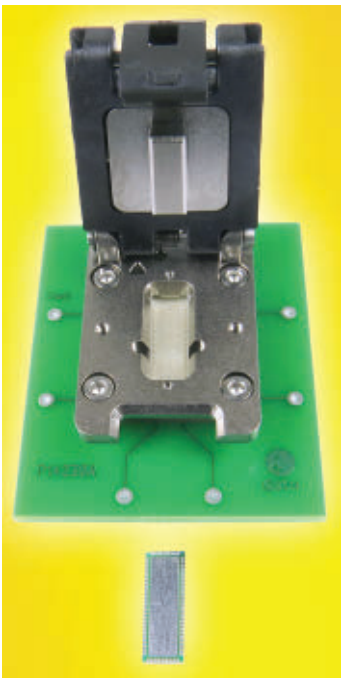
SOCKET & TEST QFN74 DEVICES WITH EXTREME TEMP SOCKET



Ironwood Electronics recently introduced a new stamped spring pin socket addressing burn-in test requirements for testing 74 lead QFN - CBT-QFN-7038s. The contactor used in the CBT-QFN-7038 socket is a stamped spring pin with 15 gram actuation force per ball with a cycle life of 10,000+ insertions. The self inductance of the contactor is 0.98 nH, insertion loss < 1 dB at 10 GHz, and capacitance 0.03 pF. The current capacity of each contactor is 2.2 amps. Socket temperature range is -55°C to +155°C.

The socket also features a clamshell lid for easy chip insertion and removal. It has a wave spring with swivel compression plate for vertical force without distorting device position. The specific configuration of the package to be tested in the CBT-QFN-7038 is a QFN, 4.5 mm x 12.5 mm, 0.4 mm pitch, with 74 peripheral positions with an additional 6x3 array of pins for the center ground pad. The socket is mounted using supplied hardware on the target PCB (printed circuit board) with no soldering, and uses the smallest footprint which allows inductors, resistors, and decoupling capacitors to be placed very close to the device for impedance tuning.

To use, place the QFN device into the socket and close the lid by snapping it to the latch. This socket can be used for quick device screening and device characterization at extreme temperatures, as well as for production burn-in testing. Pricing for the CBT-QFN-7038 is $603 (at qty 1) with reduced pricing available depending on the quantity required.

For more information, contact:
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EXPANDED CAPABILITIES FOR WAVESURFER O'SCOPE

Teledyne LeCroy has now introduced additional multi-instrument capabilities enhancing the debug effectiveness of its WaveSurfer 3000 oscilloscope. The

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addition of CAN and LIN trigger and decode capabilities to the protocol analyzer provides the tools needed to analyze and debug automotive systems using the CAN and/or LIN serial data communication standards. Arbitrary waveform generation capabilities have been added to the WaveSource function generator, enabling the import of .csv files to recreate analog waveforms.

Digital voltmeter (DVM) capabilities activate an integrated four-digit digital voltmeter and five-digit frequency counter that operate through the same probes already attached to the oscilloscope channels. Measuring and monitoring voltage levels is simple with the digital voltmeter capability of the WaveSurfer. This new feature provides real time measurements that can be viewed on the screen even when the oscilloscope is not triggering. A dedicated DVM user interface is available for set up and more measurement details. The DVM option is offered as a free software download for all WaveSurfer users.

Generating arbitrary waveforms is critical for complete design debug and validation. With new capabilities in the built-in WaveSource function generator, arbitrary waveforms can be generated by loading .csv files saved from an oscilloscope or offline waveform creation software. These arbitrary waveforms can then be controlled, manipulated, and output directly from the WaveSurfer for use in closed loop circuit analysis.

The package for the WaveSurfer includes CAN and LIN trigger and decode capabilities, and has a price of $990. The arbitrary waveform capabilities of the WaveSource are included with the function generator option and are available to existing customers with an option through a free software update. The DVM capability can be downloaded at no charge from the website.

For more information, contact:
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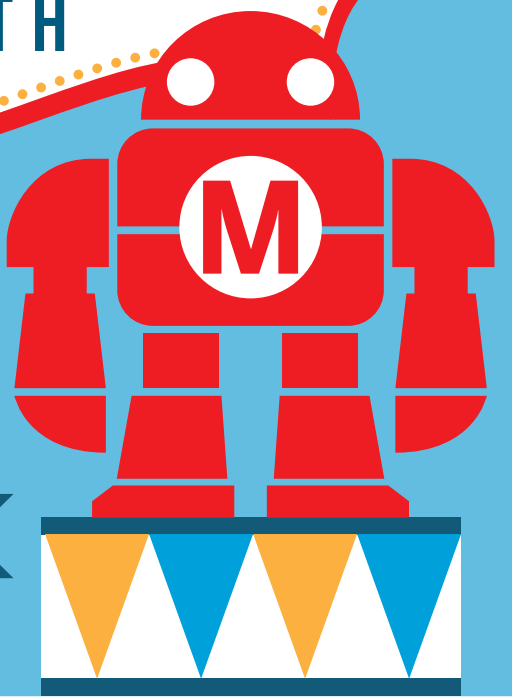

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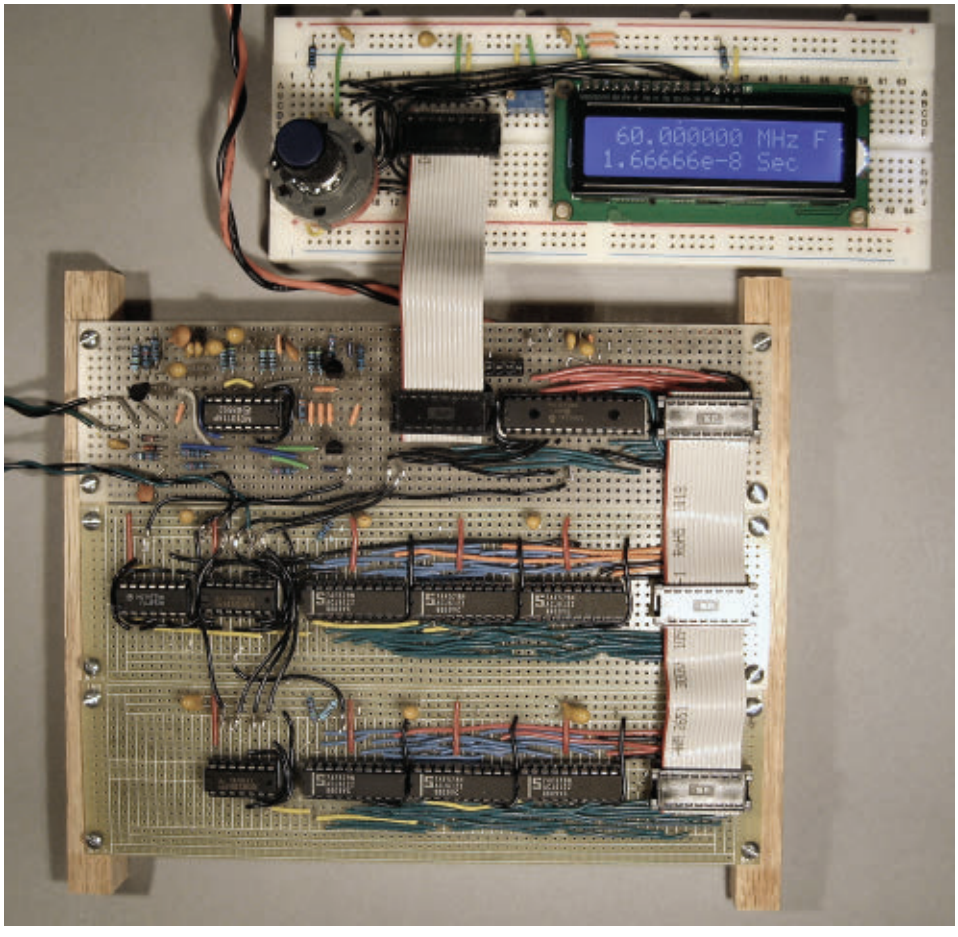
BUILD A FREQUENCY COUNTER



By Jim Teixeira

Post comments on this article and find any associated files and/or downloads at **www.nutsvolts.com /index.php?/magazine/article/ march2015_Teixeira.**

Frequency counters have been around for many years as a standard piece of test equipment in both commercial and hobby labs. It has evolved to remarkable levels of accuracy that are several orders of magnitude higher than most hobbyists could ever use. For example, I borrowed an Agilent 53131 counter to test the design of this project. The 53131 displays up to 10/11 digits of frequency that translates to reading a 10 MHz signal to .001 Hz! Counters of this type use advanced circuits called interpolators that correct the ±1 count tolerance normally stated in spec sheets. My design target for this project was seven digits, so a 10 MHz input signal could be accurate to 1 Hz, and a 10 Hz signal be accurate to .00001 Hz using a one second measurement time (without an interpolator).

Fundamentally, a frequency counter has three main components: a gate signal generator that produces a very accurate gate time interval, usually in the .1 to 10 second range; a counter chain that counts input clock pulses under control of the gate; and a control unit. For example, if the gate time is set to one second and the input signal is 5 MHz, then the counter chain will accumulate five million input pulses in the one second interval — the exact input frequency. A binary counter driven by an accurate time reference oscillator (often a 10 MHz oscillator) is usually used to get a precise one second gate interval by opening the gate for exactly 10,000,000 pulses from the reference oscillator.

This configuration works well if the input frequency is equal to or greater than the 10 MHz reference. For example, with a one second gate and an input frequency of 10 MHz, the counter will get 10,000,000 clock pulses for a 7/8 digit accuracy. However, with a 1,000 Hz input, the counter would reach only 1,000. That's just a three-digit accuracy.

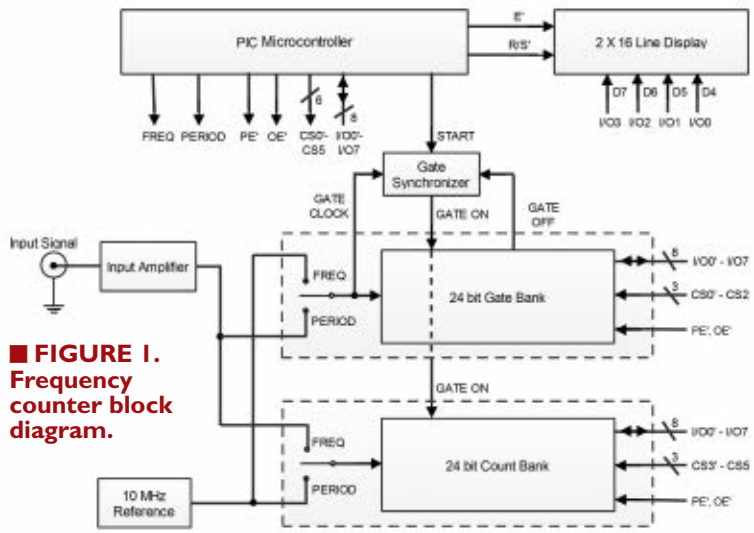
To get high accuracy for lower input frequencies, the counter itself or the user must switch to a period measurement. The roles of the gate counter and input counter are swapped. A period measurement operation (with seven-digit accuracy) is discussed under the software section of this article.

The frequency counter described here has the performance shown in **Photo 1**. All measurements use a one second gate time. At the top of **Photo 1** is the frequency measured when the input signal is the 10 MHz reference (line 1) and its period (line 2). The 'F' indicates that the reading was made by a direct frequency measurement. For the center display output, I multiplied the 10 MHz by six and made a direct frequency measurement of the 60 MHz signal. The bottom display output is the most interesting.

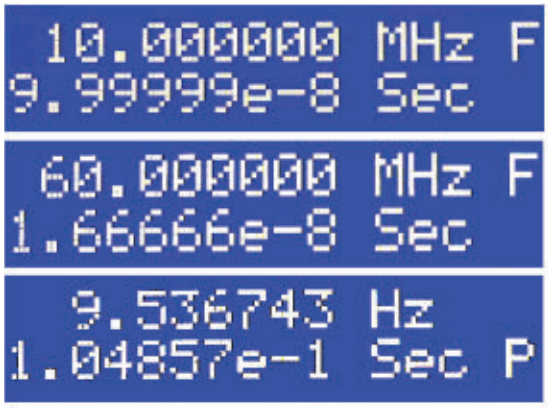
Here, I set up an external 20-stage binary counter using the 10 MHz as its input. This counter divides the 10 MHz by 2^20 (1,048,576), giving 9.536743 Hz — exactly what the display reads. In this case, a 'P' in line 2 indicates that a direct period type measurement was used. Software in the PIC microcontroller automatically chooses which type measurement (frequency or period) is best.

Figure 1 shows the major components of my frequency counter design. It's based on a 28-pin PIC16F886 and the 74F579 IC — a synchronous eight-bit binary counter with three state outputs that can operate at up to 85 MHz. This version differs from popular designs that use the PIC internal components to do the gating and counting functions. In my design, all critical timing functions are moved from the PIC to the 74F579 counters.

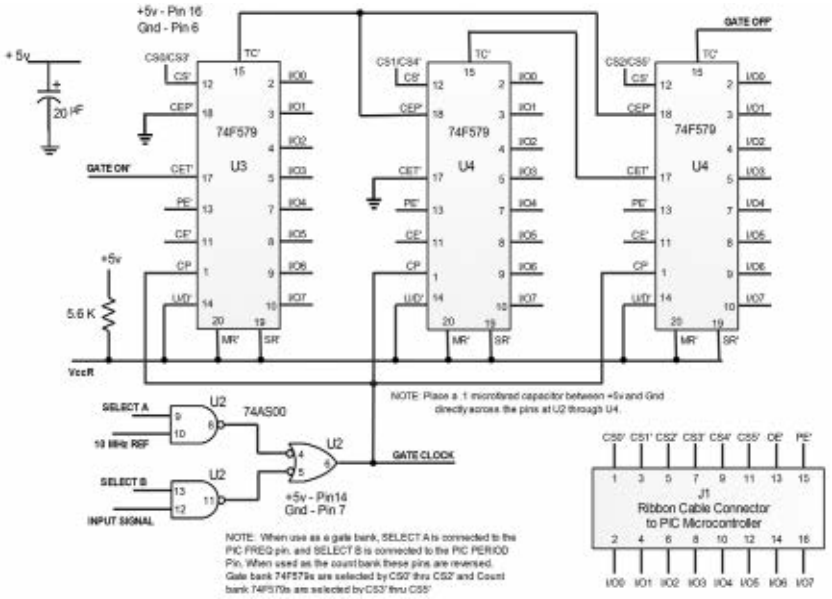
The main building block of the counter is shown in **Figure 2**. It has three 74F579 ICs in series to make a 24-



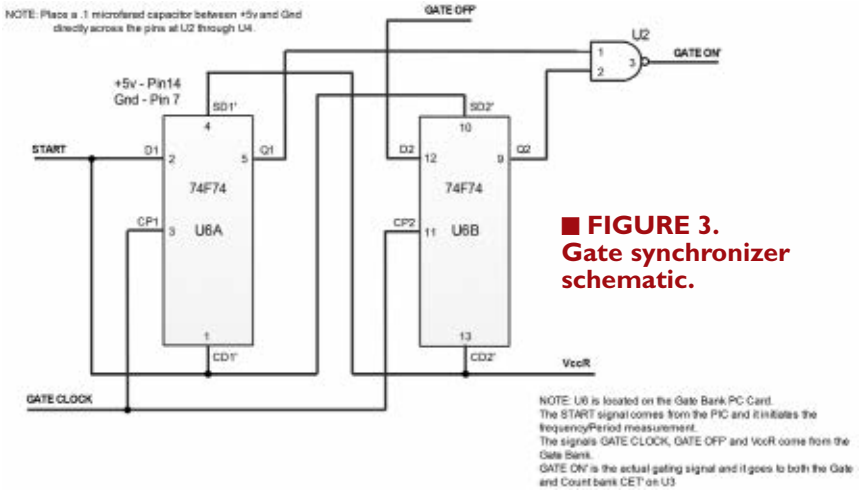
■ **FIGURE 1. Frequency counter block diagram.**



■ **PHOTO 1.**



■ **FIGURE 2. Basic counter module for both the gate and count banks.**



■ **FIGURE 3. Gate synchronizer schematic.**

bit binary counter bank, and an input switch (74AS00) to allow the PIC to control the input clock source. This building block is used as the gate signal generator and as the input counter.

The 74F579 is designed for bus operation. Its data outputs are tri-state, and are also used as inputs to preset the counter. Operation of the IC uses three control pins: CS' – Chip Select; PE' – Parallel (input) Enable; and OE – Output Enable' (the ' indicates logic low active). The PIC can address each of the 74F579s by setting its CS' pin to a logic low (0), and setting either PE' low to preset the chip flip-flops or OE' low to read the chip flip-flops. So, to preload the counter banks, the PIC sequentially performs a CS'/PE' pair individually for each of the three 74F579s in each bank. An additional U/D' pin on the 74F579 controls the counting direction. I set both banks to count up.

The 74F579 is a synchronous counter. To understand what this means, we have to look at how a traditional 'ripple' counter works. In a ripple counter, each flip-flop output is the clock input to the next stage so that the delay adds up as the stages add up. For example, if the delay between the clock input and the change in output state of the flip-flop is five nanoseconds, then since the flip-flop output is the clock input to the next stage, the delay of the second flip-flop is 5 + 5 nanoseconds. This delay 'ripples' through the counter.

In a 24-stage counter, the delay at the last stage is 5 x 24, or 120 nanoseconds. Unfortunately, this delay may vary over a two (or three) to one range just due to production variances. A synchronous counter removes the ripple effect by having each stage clocked by the same clock. The synchronous counter operation is necessary for accurate gate timing, but it's not sufficient. The gate timing must also start and stop on a clock edge. This is the reason for the gate synchronizer (**Figure 3**) which uses a 74F74 dual flip-flop.

I'll go through the process of making a simple one second frequency measurement to illustrate the gate operation. Note (as mentioned) that the gate counter is set to count up, so we set it to a value that is minus the desired count. First, the PIC presets the gate and counter banks. The counter bank is set to zero (effectively a reset operation) and the gate bank is set to minus 10,000,255 (see below). Normally, the START line is logic low, with **U6A** in the reset state and **U6B** in the set state.

The PIC starts a frequency reading by first selecting the internal reference as the gate clock and the input signal as the counter input. The PIC then sets START to a one. At the next internal reference clock pulse, **U6A** sets since **U6B** is already set. The AND gate enables the CET' pin on both counter banks, thereby starting the counting.

The TC' pin of the third stage of the gate counter goes low 256 clock pulses before the gate bank reaches its terminal count. This TC' is connected to the D input of **U6B**. On the next gate clock pulse, **U6B** is reset thus turning off the gate.

I had to preset the gate bank to minus 10,000,255

PARTS LIST

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1	309 J-FET Transistor	eBay
1	MC10116P Quad Driver	eBay
3	2N4403 PNP Transistors	**Jameco.com** 38447
2	1N4148 Diodes	Jameco 179215
6	20 µF Tantalum Caps	Jameco 545852
6	0.1 µF Ceramic Caps	Jameco 151116
1	1 µH Choke	Jameco 372357
1	PIC16F886	Jameco 2127531
6	74F579 Counter IC	eBay
2	74AS00 Gate IC	eBay
1	74F74 Dual FF IC	eBay
1	Piezo Oscillator Model 2920136	eBay
3	BPS BR1 PC Breadboard	Jameco 2125034
5	16-pin Ribbon Cable Connector	Jameco 42674
1	16-conductor Ribbon Cable	Jameco 643831
Various 1/4 watt ±5% metal or carbon film resistors		

because the TC' occurs 256 pulses early and I add one clock pulse for synchronizing, so I add minus 256 plus 1 to the desired gate time. Because the gate bank starts and stops exactly on a clock pulse (because of the gate synchronizer) and the delay through the counter is very low, the gate timing is very accurate. At the end of the gate time, the PIC reads the count bank outputs to get the frequency.

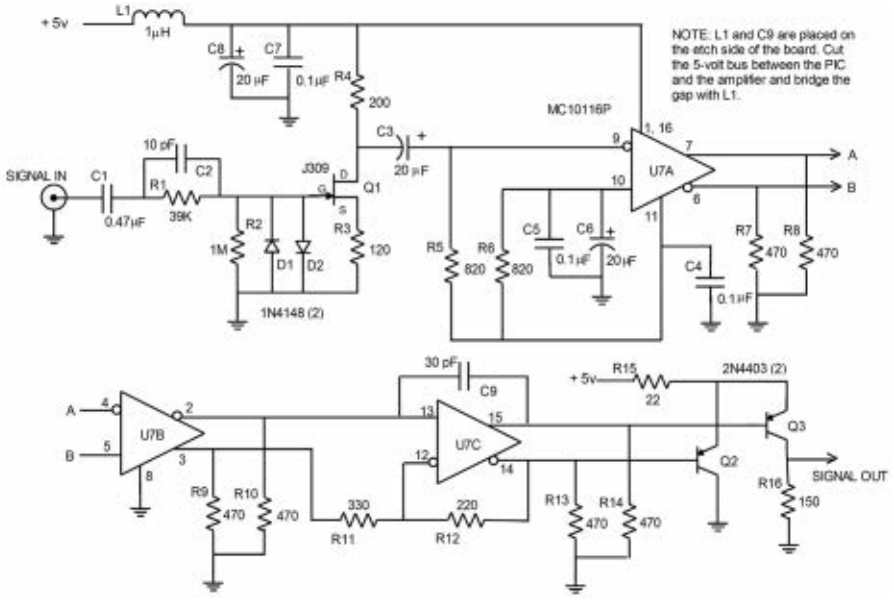
Making a period measurement follows a similar path, except the gate bank and count bank inputs are reversed by **U2**. The PIC preloads the gate bank with a value equal to minus the number of input signal pulses minus 255. For example, to count 1,000 signal pulses, the gate bank is loaded with minus 1,255 (minus 1,000 minus 255). Period measurements are a little more complex since we have to pick the number of input signal pulses (the 1,000 in this example).

The accuracy of the measurement depends on how many internal reference clock counts are accumulated in the count bank. If we use the 1,000 signal pulses discussed here and the input signal is 1,000 Hz, then the gate will be open for one second and the count bank will record 10,000,000. This gives us our 7/8 digit accuracy.

However, if the input signal frequency is 100 kHz, the gate will be open for .01 seconds and the count bank will record 100,000 or 5/6 digit accuracy. On the other hand, if the input signal frequency is 10 Hz, the gate will stay open for 100 seconds. As we'll see shortly, the software (available at the article link) solves this problem nicely and will force a gate time of close to one second (or whatever value we want). Five more components complete the block diagram shown in **Figure 1**:

1. The input signal amplifier.
2. The rotary switch input circuit.
3. The PIC16F886.
4. The display.
5. The internal 10 MHz frequency reference.

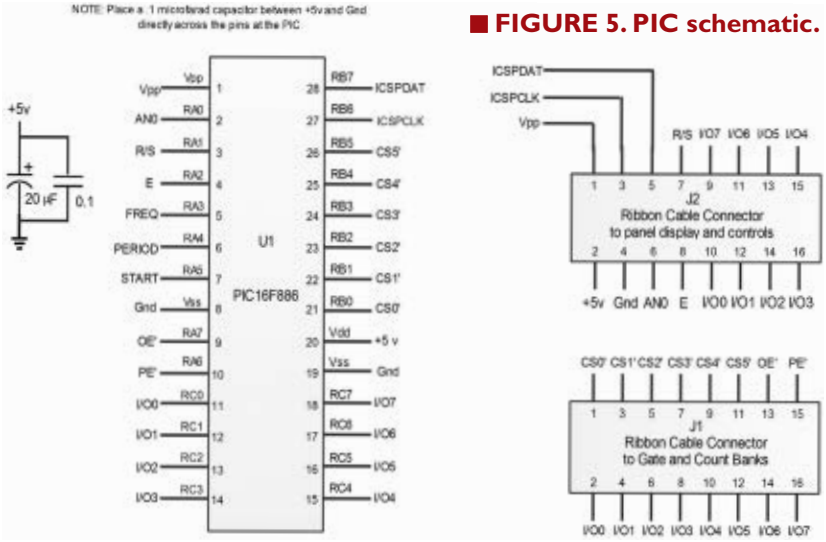
The input signal amplifier (**Figure 4**) is used to take a low amplitude input signal with a frequency range of 10 Hz to over 70 MHz and convert it to a TTL voltage level. Every frequency counter has some sort of input amplifier and the Internet is full of designs ranging from simple two-transistor FET amplifiers to multi-component designs often using the popular MC10116 ECL triple line receiver.



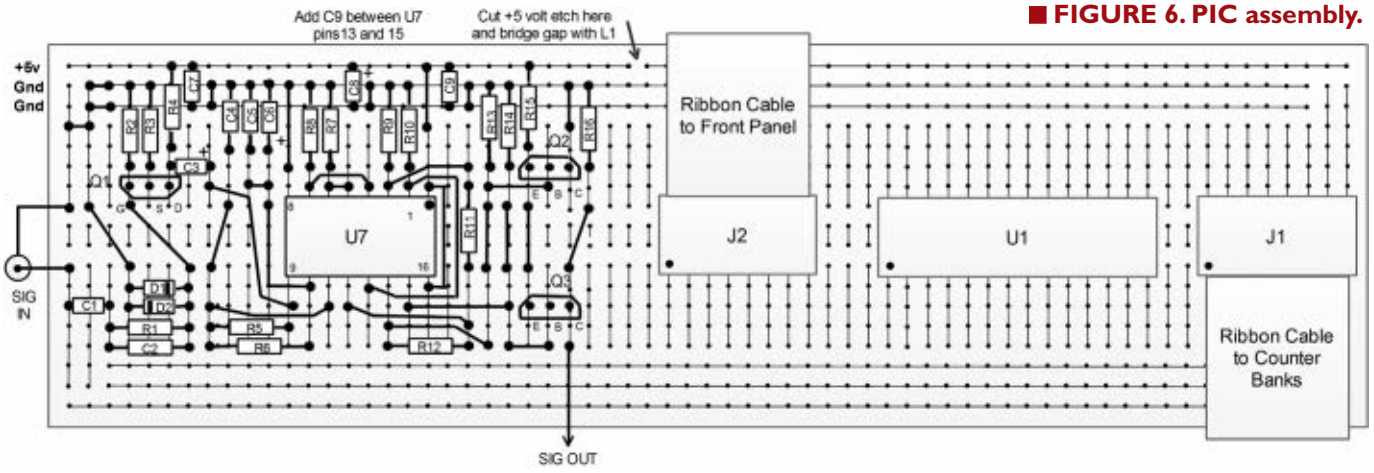
■ **FIGURE 4. Input amplifier schematic.**

The frequency range can be increased to the 300 MHz range, or even higher by using a prescaler. Again, the Internet has many designs for this. The rotary switch input circuit is simply a four-resistor voltage divider, with the voltage taps connected to the switched terminals of a rotary switch. The switch wiper terminal connects to RA0 on the PIC, and the PIC A/D converter determines the switch position by simply reading the voltage on pin RA0. The software recognizes three switch positions:

1. Make high accuracy (7/8 digit) readings (top tap of the switch). These take about 1.3 seconds per reading.
2. Make medium accuracy (6/7 digit) readings (center tap). These take about .6 seconds.
3. Make continuous (5/6 digit) readings (bottom tap). These take about .1 seconds.



■ **FIGURE 5. PIC schematic.**



■ **FIGURE 6. PIC assembly.**

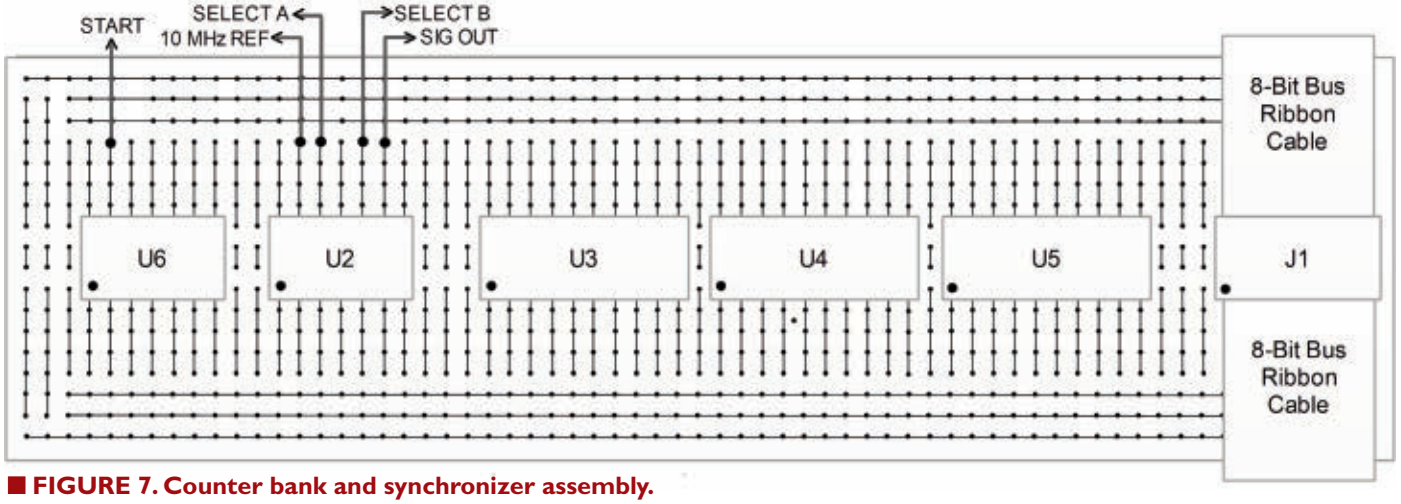
I chose the PIC16F886 (see **Figure 6**) because it is a cheap popular unit that does the job without overkill. Since there are no critical timing requirements, the internal 8 MHz oscillator works fine. This PIC also has just enough I/O pins (22 available). If you want to add RS-232 or USB, then try the PICF887. It has plenty of I/O and has USB support.

The display for this project is a 2x16 backlit alphanumeric version. This type of display usually connects with four-bit data bits, but sometimes eight bits are used (these bits are shared with the 74F579 bus) and two control signals (R/S' and E'). Fortunately, most compiler products include display drivers so you don't have to understand the inner workings of the display. (Look ahead in **Figure 8** for the front panel components and connectivity.)

The top line is used to display the input frequency in 7/8 digits, plus up to two commas or a decimal point. This is followed by 'Hz' or 'MHz' and the letter 'F' when the gate is on and making a frequency measurement. The second line simultaneously displays the period of the input signal in scientific notation (like 1.2534E-6), followed by 'Sec' and a 'P' when the gate is on and making a period measurement.

The final item in **Figure 1** is the internal frequency reference. The measurement accuracy is totally dependent on the accuracy of the gate time, and thus on the accuracy of the internal frequency reference. The design goal of seven digits is within an oven-controlled crystal oscillator range. I used a piezo model 2920136 10 MHz oscillator that I bought on eBay for $25. It outputs a TTL square wave and warms up to seven-digit accuracy in about five to 10 minutes. Unlike cesium, rubidium, or GPS references, oven-controlled crystal oscillators have to be calibrated initially. If you don't have access to a calibration facility, then here is an alternate technique that works.

The National Institute of Standards and Technology's (NIST) radio station WWV broadcasts high accuracy signals at several shortwave frequencies, including 10 and 20 MHz. These transmissions contain exact one second time markers, but the carriers themselves are also exact frequencies set by their cesium standards. If you tune a shortwave radio to one of the WWV frequencies at 10 or 20 MHz, you will hear the one second time ticks and

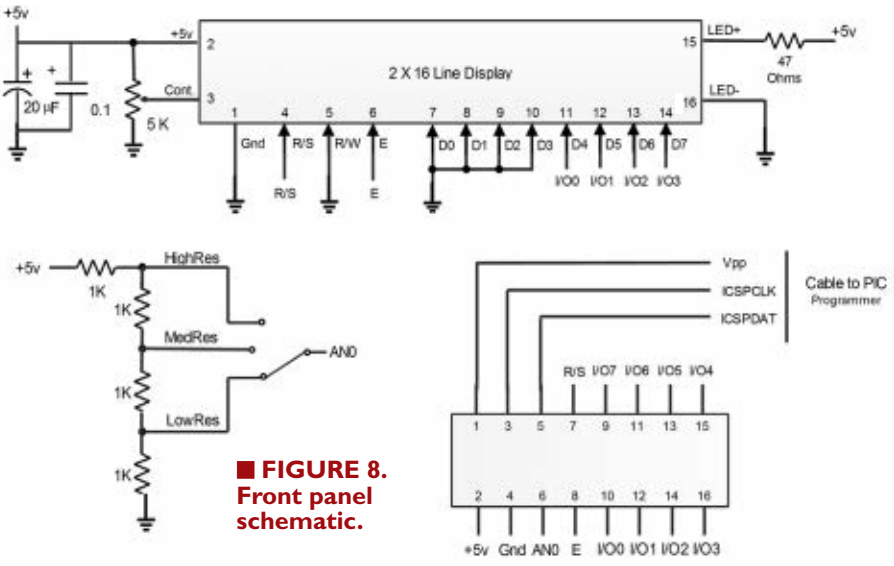


■ **FIGURE 7. Counter bank and synchronizer assembly.**

some voice messages.

Now, move the radio close to your oscillator and vary the oscillator frequency adjuster until you hear a beat tone as the oscillator frequency approaches and passes through the WWV carrier frequency. As you get very close to the WWV frequency, the beat tone will become inaudible, but you will hear the noise level change in amplitude as the oscillator goes in and out of phase with WWV. It will sound like swoosh ... swoosh ... swoosh.

If you are tuned to the 10 MHz and the swooshing sounds repeat once per second, then the oscillator is accurate within one part in 10,000,000. It's not difficult to do five or ten times better.



■ **FIGURE 8. Front panel schematic.**

Software

Off-loading the critical frequency counter functions to hardware makes the software control very straightforward. Basically, to make a frequency measurement, the software preloads the count registers to zero; the gate counter to the measurement period (.1 sec, 1 sec); the FREQ bit to one (to set the gate bank input to the 10 MHz reference and the count bank input to the input signal); and finally, the START bit is set to one.

After waiting for the measuring period to end, the software reads the count registers to get the frequency directly for a one second gate or frequency/10 for a .1 second gate. Making a period measurement follows a similar course, except the PERIOD bit is set to connect the gate bank input to the input signal and the count bank input to the 10 MHz reference. The key here is determining what value of input signal pulses to assign to the gate counter.

A *HighRes* measurement starts with the software making a sample .1 second frequency measurement. The measured frequency is multiplied by 10 to get the actual frequency. If the actual frequency is equal to or greater than 10 MHz, then the software goes on to make a higher accuracy one second frequency measurement. Otherwise, the software makes a period measurement by setting the gate counter equal to the actual frequency from the .1 second frequency measurement.

This means that the gate time will be close to one second and the count bank will reach close to 10,000,000, giving 7/8 digit accuracy. Note: We want the gate time to be about one second only to get the desired 7/8 digit accuracy. The frequency will be calculated using the number of 10 MHz pulses accumulated, and the count value preset into the gate counter.

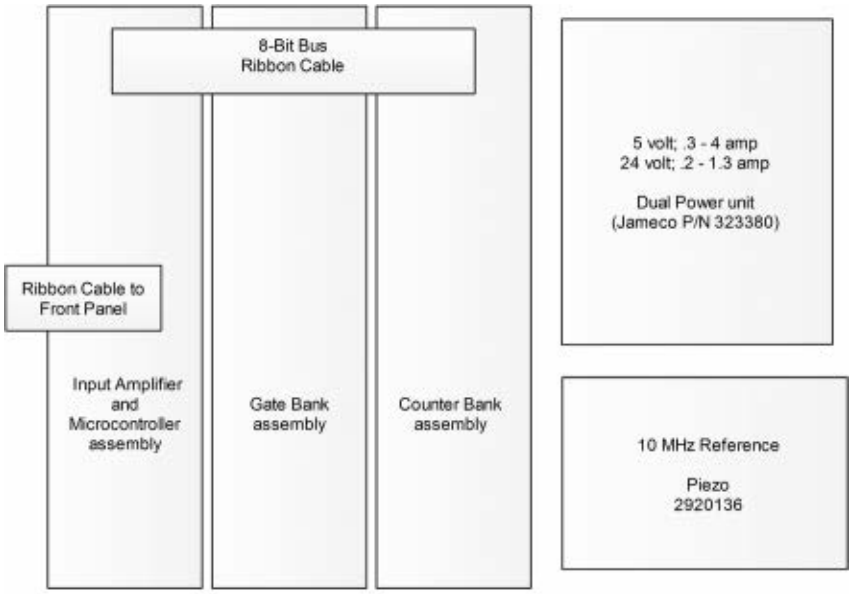
For example, suppose the input frequency is exactly 992.150 Hz and the .1 second reading is 99. We multiply 99 by 10 to get 990, then this value (actually minus 990 minus 255) is set into the gate counter. The gate open time will be 990/992.150, or .9978329 seconds — close enough to the desired one second. The counter bank will end up at 9,978,329. We now calculate the actual frequency as 10,000,000/9,978329 X 990 = 992.150 Hz.

Note that the counter banks are only 24 bits long, giving a total count of 2^24 or a maximum count of 16,777,216. This is fine for the gate counter since its maximum count is about 10,000,000. However, for a high input frequency, the counter bank could exceed 60,000,000. I get around this by using a counter wrap-around property. When the count equals the maximum, it wraps around and starts again at zero. So, a 60,000,000 count will actually be 60,000,000 – 3 x 16,777,216 = 9,668,352. This begs the question of how do we know that the counter over-flowed three times. It's simple. When I make the .1 second measurement, I divide by 1677721 and the number of counter wrap-arounds is the integer result – (integer)6,000,000/167721 = 3.

Construction

The unit is built on three solderable prototype PCBs (printed circuit boards; Jameco part 2125034). One board (**Figure 6**) houses the input amplifier (**Figure 4**) and the PIC16F886 circuits (**Figure 5**). (An optional design is to mount the input amplifier in a separate shielded enclosure.) I isolated the five volt bus for the preamplifier by cutting the five volt etch between the input amplifier and the PIC. I then bridged the cut with a 1 µHenry choke. A second board (**Figure 7**) contains a counter bank (**Figure 2**) and the gate synchronizer (**Figure 3**). The third board (**Figure 5** without **U6**) contains just a counter bank (**Figure 2**).

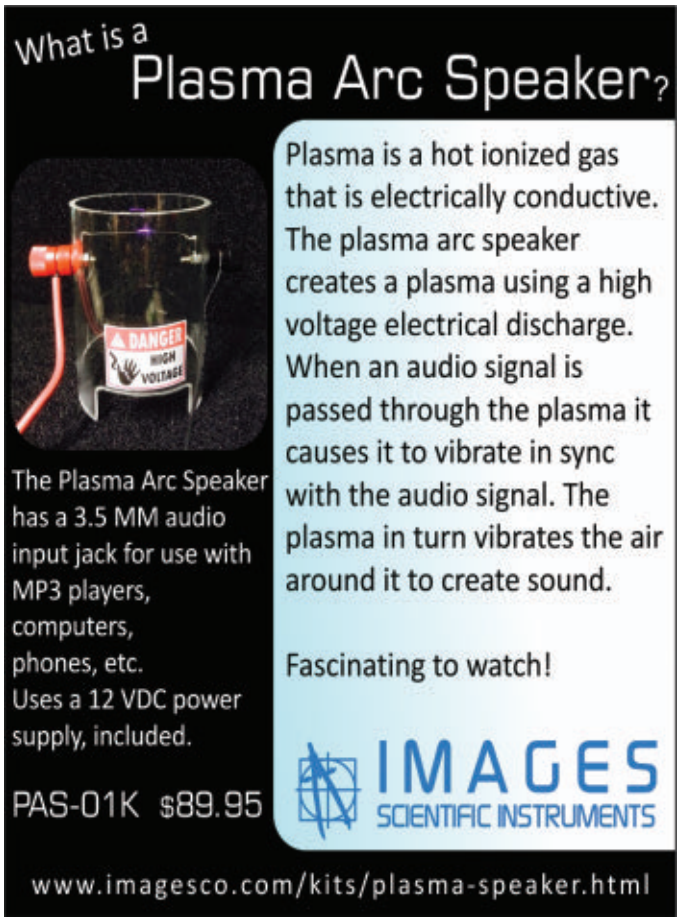
■ **FIGURE 9. Frequency counter assembly.**



The three boards are connected together via a short 16-conductor ribbon cable that contains the 74F579 data bus and selection and control signals. The microprocessor board also contains a 16-conductor ribbon cable connector for the front panel display and controls. The boards each measure 7 inches x 1-7/8 inches. When mounted with the long sides adjacent, the total footprint of the counter electronics is about 7 inches by 6 inches. The unit uses about one ampere of five volts for the digital circuits and less than .5 amperes at 24 volts for the piezo oscillator. Most dual 5/24 volt power supplies will work.

Figure 9 shows the main component layout. The footprint is approximately 8 inches x 10-1/5 inches. I purchased all of the parts through either Jameco or eBay. The digital components cost less than $30, and the oscillator and power supply cost a total of $55.

For software development, I chose the mikroC Pro compiler and a cheap PICkit 2 to program the microcontroller. The software design does not use interrupts and can easily be programmed in assembly language or BASIC, as long as floating point arithmetic is available. Now, go get your "freq" on! NV



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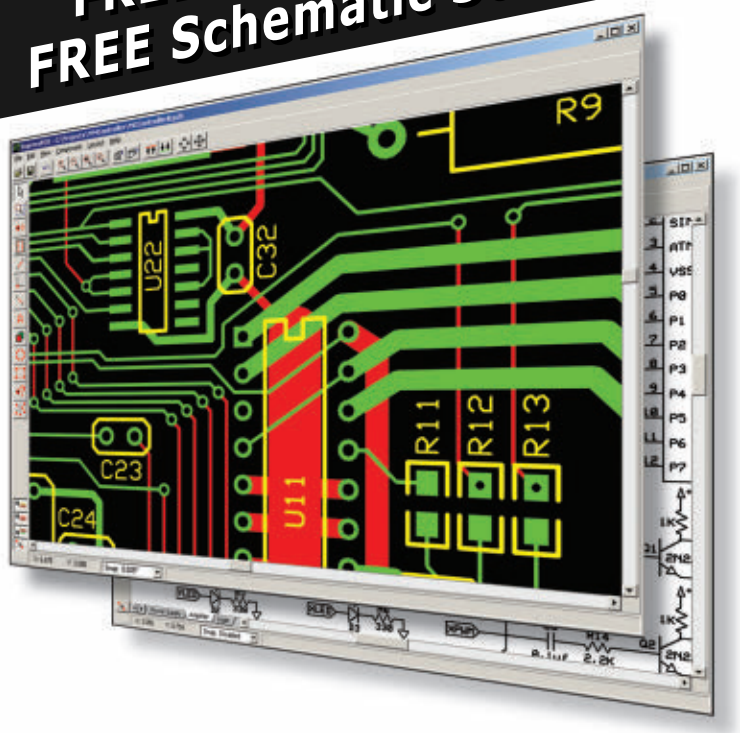

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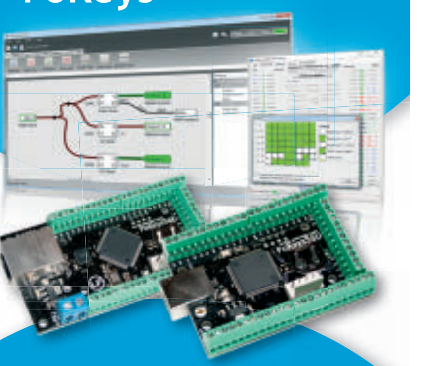

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By Alan Grambo

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A COST-EFFECTIVE TRAFFIC LIGHT CONTROLLER

Every Digital Electronics' Lead The Way (see sidebar) student has had to build a traffic light controller for a lab assignment. Usually, they are required to build a digital circuit using discrete digital components. The student is then required to use the digital circuit to illuminate Light Emitting Diodes (LEDs) which typically draw 20 milliamps. Some digital circuits can provide this small current directly without the use of drive transistors or relays.

More sophisticated students might make use of an Arduino board to design an even better circuit. The advantage of using an Arduino board is that the design allows the use of proximity sensors to detect the presence of a vehicle in a turn lane, and have the Arduino program change the timing of the lights accordingly. The Arduino has input lines to change the timing of all the light outputs. Those who use an Arduino board for this purpose can find many methods of programming it on the Web.

What is Project Lead The Way?

Project Lead The Way (PLTW; **www.pltw.org**) classes are now held in more than 6,500 K-12 schools in the US. These classes help students develop skills for today's world by aligning themselves with Science, Technology, Engineering, and Math (STEM) programs. PLTW classes are typically taught by instructors that have been trained in a professional development PLTW class.

There are many different genres of PLTW classes available. Here is a brief list of some of the classes being taught in schools:

Introduction to Engineering Design
Principles of Engineering
Aerospace Engineering
Biological Engineering
Civil Engineering and Architecture
Computer Integrated Manufacturing
Computer Science and Software Engineering
Computer Science Applications
Artificial Intelligence
Biomedical Innovation
Digital Electronics
Engineering Design and Development
Principles of Biomedical Science
Human Body Systems
Medical Interventions
Biomedical Innovation

Digital Electronics is just one of the choices of possible classes offered. Each school decides which PLTW class to offer, based on instructor availability and what classes the students might desire to take. As an example, one of the assignments in the Digital Electronics class at Fishers High School in Fishers, IN is to build a traffic light controller.

A Programmable Logic Controller (PLC) could also be used to control the traffic light bulbs. The PLC has the capability of receiving inputs to control the outputs to the colored lamps.

The problem becomes a little more complex when you design the circuit to operate like a real traffic light rather than to control low current LEDs. Real traffic lights have either eight inch lenses or 12 inch lenses, with 150 watt incandescent lamps inside. This size bulb takes about 1.3 amps with a surge of about nine amps when first energized, so relays would normally be required to operate the lamps reliably. You could use a Silicon Controlled Rectifier (SCR) to control the higher current, but SCRs have a habit of being unreliable because of the large surge current required to illuminate incandescent lamps.

A former co-worker of mine has 110 real full-size traffic lights that have no control circuits. So, they cannot work as regular traffic lights do. He approached me because he wants to sell them, and he wants to be able to offer the buyers control circuits for the lights if they wanted them. Concerned about the cost of such control circuits, he asked if I could come up with a circuit that would cost less than $20 to build.

I first designed an Arduino circuit to control the traffic light. The main problem with building the Arduino circuit was that it would be too expensive. The Arduino Uno board would cost $25; the drive transistors, relays, and power supply would cost more than $20. It would be a versatile multi-function controller, but the cost was beyond my co-worker's budget.

I then designed and tested a circuit that used two 555 IC timers that worked well, until I added the relays and driver transistors to the circuit. The inductive kickback of the relays — even with protective diodes — caused the 555 circuits to trigger at the wrong time, so the circuit would skip a lamp periodically. Also, the sequence would sometimes be yellow-green-red rather than yellow-red-green.

The second digital circuit I tried used a 555 timer, a 4017 decade counter, 13 diodes, three drive transistors, and three relays. With these parts, I was able to arrive at a suitable operational circuit. This design, however, had a

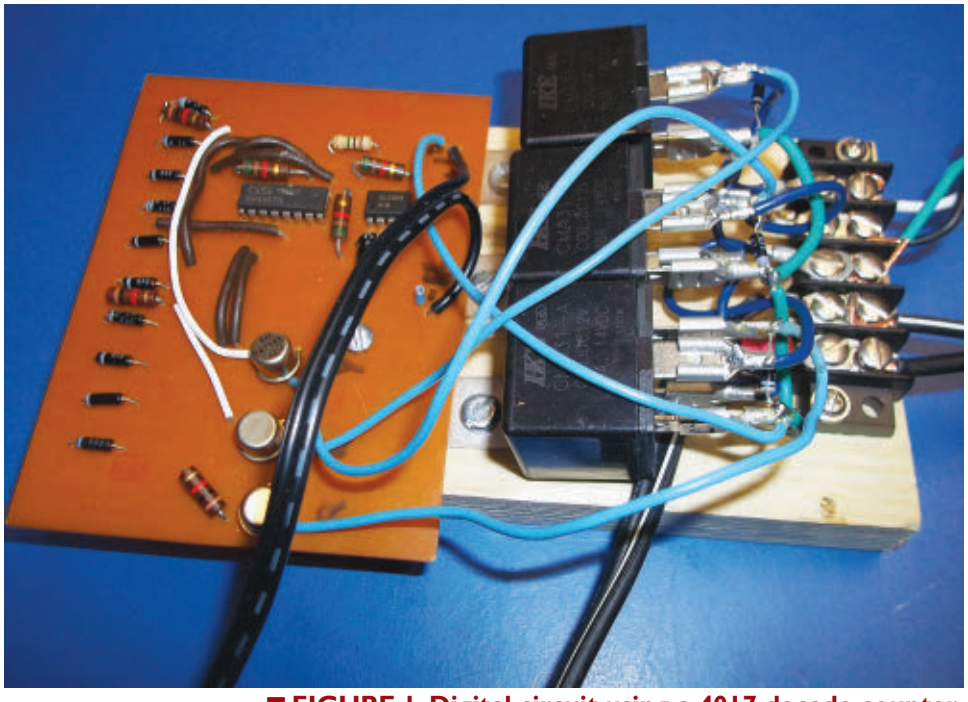
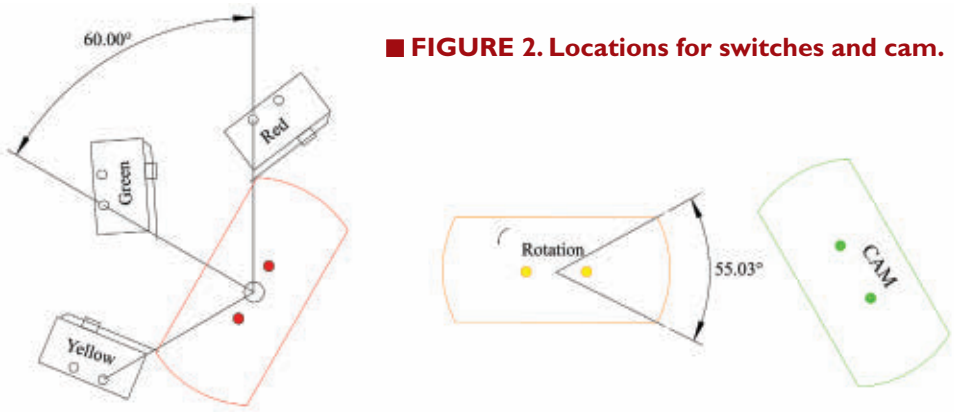


FIGURE 1. Digital circuit using a 4017 decade counter.



■ **FIGURE 2. Locations for switches and cam.**

parts cost over $20 and would have required a printed circuit board (PCB) to be designed and stuffed with parts, plus a 12 volt power supply to operate the relays. Again, the parts cost was too high (**Figure 1**).

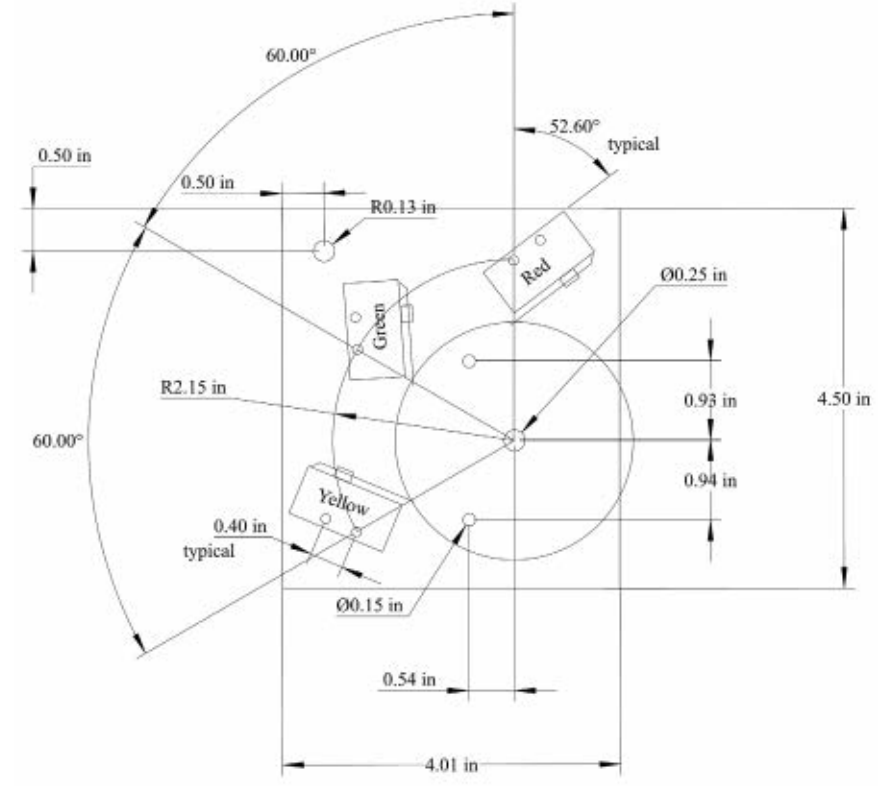
For the least expensive circuit, I used limit switches. With limit switches and a mechanical design, I built an inexpensive control circuit for a real traffic light. In this case, a simple mechanical design was less costly.

The limit switches can directly handle 120 VAC and the nine amp surge current. These limit switches needed to be mechanically operated. If I used a gear motor running at one revolution per minute, I could design a cam to activate the limit switches. If I used three limit switches located 60 degrees apart — activated by a dual-pronged cam that was 60 degrees wide — each light would be on for about 10 seconds.

I needed a Computer Aided Drafting (CAD) program to lay out the switches with different cam positions to see if the parts would mesh correctly. When I taught Project Lead the Way Engineering and Drafting, I used Autodesk Revit and was able to lay out parts like this. However, I do not presently have access to that program. So, I purchased TurboCad 18, which is a great program for a reasonable price ($39.99 at **Amazon.com**; **Resource 1**).

I found that TurboCad was able to lay out the switches in a variety of ways, and I could visually verify how the cam and switches would interact. Using the first layout, the prototype caused the gear motor to bog down since the cam was pushing on the switch directly instead of pushing on the lever arm to provide some mechanical fulcrum leverage. Modifying the TurboCad drawings was easy, and it was fun to have a nice drawing program to work with.

If I asked the program to print out the drawing on my Brother MFC-7360N printer in a drawing scale of 1/1, the drawing was accurate to within the width of a printed line. This allowed me to cut out the printed drawing and use it as a template to make the parts. This may not be the case for every computer/printer combination, but it was sure nice to have a template for making my parts. TurboCad did a nice job in my situation and saved me from having to measure the dimensions on the drilled



■ **FIGURE 3. Mounting hole dimensions.**

Author Bio

Alan Grambo was an electrical engineer for 28 years who worked on smart bombs for the Navy. He retired to teach high school electronics students. He has also worked as a forensic engineer for lawyers and insurance companies to investigate the causes of accidents and fires.

He is a nationally recognized tournament table tennis player and has played table tennis in over 20 states, Canada, and Finland. He now teaches electronics to his grandkids by building gadgets with them.

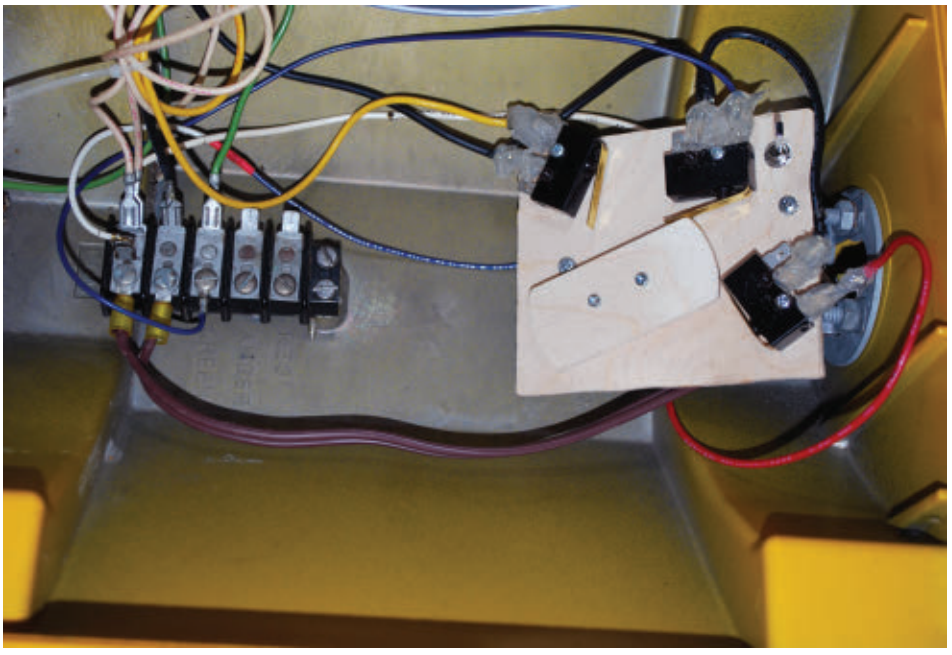
boards. As a project engineer, I used to sign off drawings with a note, "Do not scale drawing." If a drawing had a missing dimension, the machinist had to call the mechanical engineer to correct the drawing so that a bad part would not be made. If you have a good 1/1 scale print, then dimensions may not be necessary.

The second optimum layout is shown in **Figure 2**. The best design used a 55 degree arc for the cam. If you use 60 degrees, two lights will be on at the same time. The idea is to have one light turn on when the other goes off. If your cam has two lights on at the same time, it is easy to sand the corner off the cam to allow fine adjustment on the light timing.

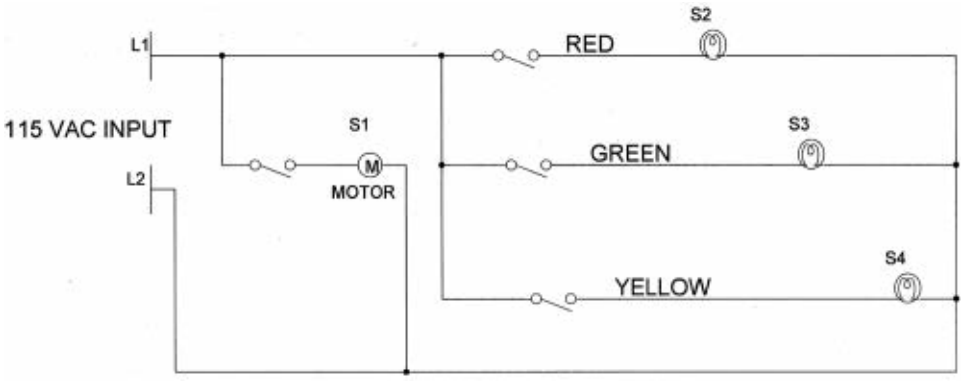
I added a toggle switch in series with the motor power line; the user can stop the motor movement so one light might be on all the time.

The mechanical design was the least expensive of all the controllers because I was able to find a surplus 50 RPH gearmotor for $1.89 (**Resource 2**) and the limit switches for $0.75 each (**Resource 3**). I also found a 12 x 12 x 1/8 inch plywood board at Tower Hobby for $2.98.

The cam can be made from this plywood plank or you can use a 1/8 inch piece of clear plastic to fabricate the cam. Using limit switches solves the current-handling problem while providing a reasonable cost to implement an effective circuit.



■ **FIGURE 4. Controller board installed in traffic light assembly.**

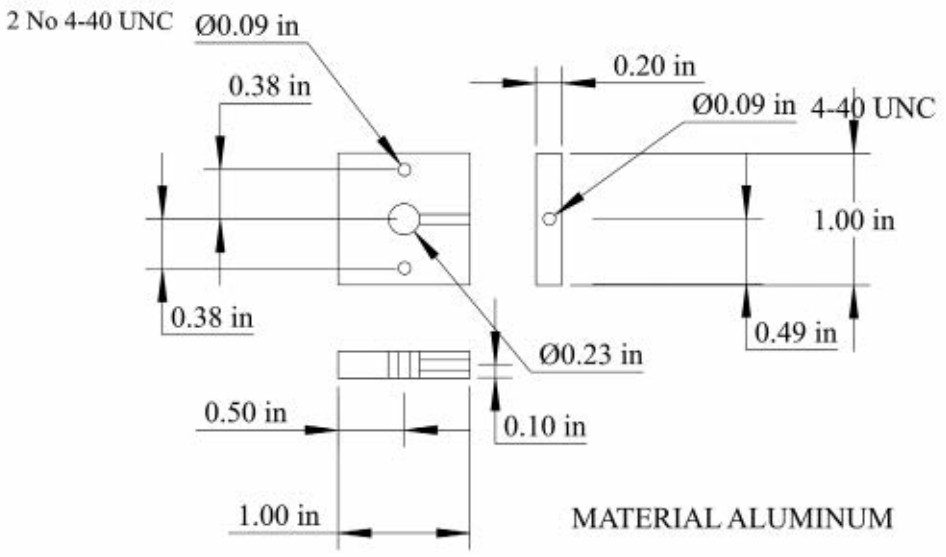


■ **FIGURE 5. Schematic of traffic light wiring.**

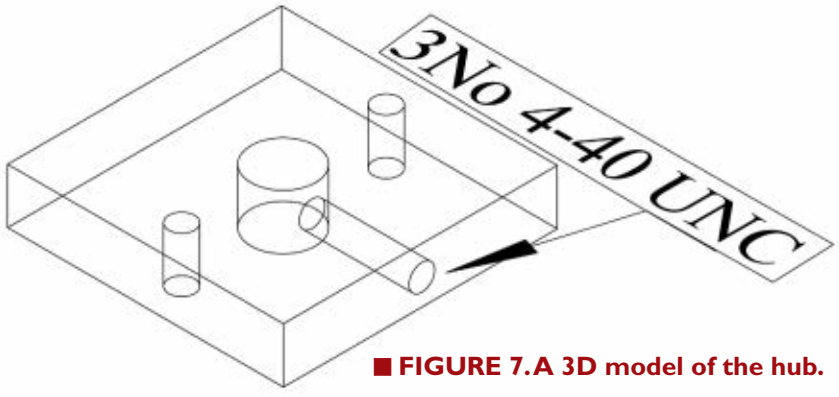
The TurboCad 18 dimensions for the mounting holes are shown in **Figure 3**, **Figure 4**, and **Figure 5**.

PARTS LIST

ITEM	QTY	PRICE	TOTAL	SOURCE
Limit Switch	3	$0.75	$2.25	www.allelectronics.com/make-a-store/item/SMS-309/10A-SNAP-ACTION-SWITCH/1.html
50 RPH Gearmotor	1	$1.89	$1.89	www.surpluscenter.com/Electric-Motors/AC-Gearmotors/AC-Gearmotors/50-RPH-115-VAC-INLINE-GEARMOTOR-10-958-A.axd
1/4" Mount Hub	1	$4.00	$4.00	www.pololu.com/product/1993
Mounting Board	1	$0.50	$0.50	1/8 plywood board from local hobby store — use to also make cam
Lugs	9	$0.16	$1.44	www.newark.com/molex/05-06-0301/unknown/dp/54H5270
Power Cable	1	$2.49	$2.49	15 foot extension cord from local hardware store
Motor Switch	1	$1.25	$1.25	www.allelectronics.com/make-a-store/item/mts-4/spdt-on-on-mini-toggle-switch/1.html
TOTAL			$13.82	*Prices subject to change without notice.*



■ **FIGURE 6. Dimensions to make the square hub.**



■ **FIGURE 7. A 3D model of the hub.**

The cam was originally mounted on a Pololu mounting hub #1993 which added about $4 (**Resource 4**). Again, I used TurboCad 18 to lay out a new hub and had the local high school Career Center machine shop class fabricate hubs to the TurboCad 18 drawings shown in **Figure 6** and **Figure 7**. The schematic shows that a switch is in series with the gearmotor to allow it to be turned off (**Resource 5**).

This allows the operator to turn on just one light and leave it on all the time (**Figure 8**). I have a friend who stated that if he displayed a continuous green light, that meant that it was okay to visit his man-cave; a continuous red light meant to stay away.

Lugs to connect to the switches and to the terminals in the traffic light housing can be obtained from Newark (**Resource 6**).

Upgrade Possibilities and Other Applications

Because of the symmetry of the cam and the spacing of the limit

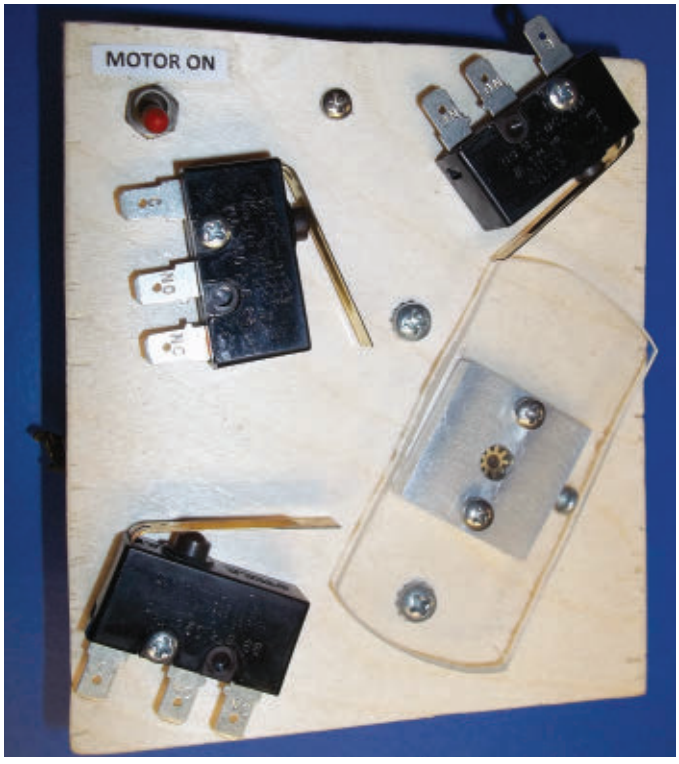
RESOURCES

ITEM	SOURCE
Resource 1	www.amazon.com/TurboCAD-Windows%C2%AE-8-7-Vista-XP/dp/B00DDV74FC/ref=aag_m_pw_dp?ie=UTF8&m=AWG7LPR0FBMV7
Resource 2	www.surpluscenter.com/Electric-Motors/AC-Gearmotors/AC-Gearmotors/50-RPH-115-VAC-INLINE-GEARMOTOR-10-958-A.axd
Resource 3	www.allelectronics.com/make-a-store/item/SMS-309/10A-SNAP-ACTION-SWITCH/1.html
Resource 4	www.pololu.com/product/1993
Resource 5	www.allelectronics.com/make-a-store/item/mts-4/spdt-on-on-mini-toggle-switch/1.html
Resource 6	www.newark.com/molex/05-06-0301/unknown/dp/54H5270

switches, each light is on for approximately 12 seconds and does not duplicate the normal short on time for the yellow light in a regular traffic light. A future modification might be to design a different cam and/or different switch locations so the yellow light is on for a shorter duration. This might be accomplished by having an upper and lower cam with the limit switches at different heights.

The controller could also be used for sequencing Christmas light decorations or attention-getting advertising booth chaser lights. The unit cost for parts for the finished controller was $13.82 when I purchased enough parts for 20 units.

This interesting mechanical design using limit switches provided a cost-effective solution for an entertaining project. **NV**



■ FIGURE 8. Controller with new square hub and plastic cam.

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Beyond the Arduino

Getting Started with AVR Microcontrollers

I bet that you've built some amazing projects with your Arduino — it is an incredible platform. At some stage, though, you're likely to want to cut the apron strings and discover what it's like to work directly with the microcontroller. This series of articles is designed to make your journey a little less bumpy.

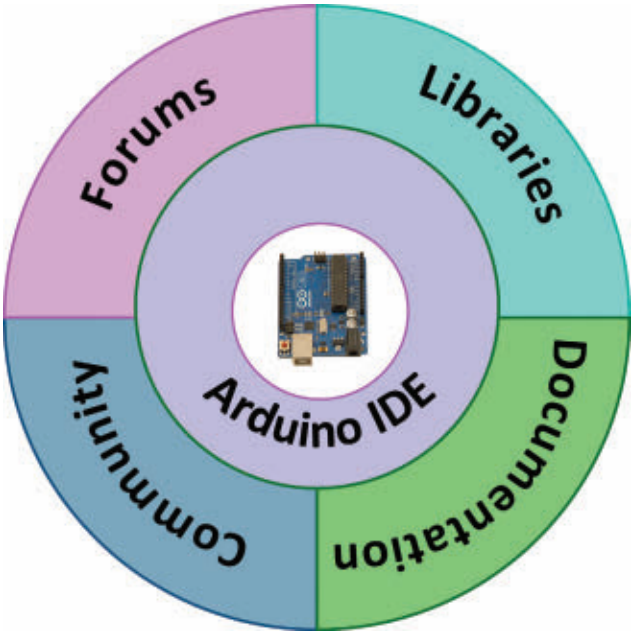


FIGURE 1. The Arduino ecosystem.

Heading Towards the Light

A number of years ago, I discovered the excitement of using software to physically interact with my environment. As a software developer, it was an eye opener when I found that I could write code that would make a robot drive around a room avoiding obstacles. It was so much more "real" than writing code to manage warehouse stock levels or generate invoices.

Like many others, an Arduino Uno was my introduction to this crazy world of physical computing. I spent hours building robots, temperature sensors, the obligatory flash-lots-of-LEDs projects, and alarm clocks. You name a tutorial, I had read it. However, in my hunger to build more and more complex and interesting embedded projects, I found I was hitting up against the limits of the simplified Arduino environment. The processing language sitting on an all-in-one development board got me up and running very quickly and taught me a great deal, but now I needed to spread my wings and start working directly with the microcontroller.

The tipping point was an irrigation controller I was working on. My garden was drying out in the summer heat, so I turned my mind to building an irrigation controller, then turned my hand to the (occasionally disastrous and very damp) task of plumbing in my solenoid valves. I learned a great deal that summer, and finally had a green garden that was being watered to schedule — thanks to a microcontroller-based project.

The journey away from the safety of the Uno was a tough one. There was an almost endless supply of information I found on the Internet, but the snippets were fragmented and didn't form a cohesive guide to take me from the Arduino ecosystem to a stand-alone "bare metal" microcontroller project. I stubbed my toe, banged my head, and slowly waded through a barrage of online tutorials, blogs, forums, Wiki articles, and Instructables to arrive out the other side with a degree of competency.

Through my journey, it became apparent that there were many others in a similar situation to me. As the Arduino platform matures as a product and as hobbyists become more serious enthusiasts, more people are looking to take the next step and move beyond the Arduino. I do hope that I can help you head towards the light in this series of articles.

How do Microcontrollers Differ from the Arduino?

The Arduino is often referred to as an ecosystem. It is similar to a natural ecosystem in the way in which the various elements inter-relate and depend on one another. The core elements in the ecosystem are the physical boards and the software integrated development environment (the IDE and the Arduino libraries), which are then surrounded by the documentation, the support structures, and the larger Arduino community (**Figure 1**).

In moving away from the Arduino ecosystem, you are leaving these behind, but that doesn't mean you're moving into an environment without these inter-relationships. These elements exist in some form or another, but are not as neatly packaged or as accessible.

A microcontroller by comparison is just one of the components that make up a physical Arduino board — it is the most important element as it is effectively the "brains" of the board. In order for a microcontroller to function, it needs only a few simple components and regulated power. The Arduino Uno that I used supported the microcontroller by housing these parts and providing it with a steady clean supply of power.

My Uno went a few steps further by giving me a way to communicate with the onboard microcontroller. A stand-alone microcontroller can't communicate with a PC, so Arduino cleverly incorporated USB connectors to make this happen. The main reason to open a communication channel is to allow you to program the microcontroller — there's not much point working with one otherwise!

Secondly, by using a serial terminal, you can communicate with your sketch while it's running — I use this extensively for debugging. Also on the Uno is a second microcontroller that handles the translation from serial to USB. On newer boards (like the Leonardo), the main microcontroller has the ability to do this.

This might all sound rather complicated, but by the end of this article you'll have built your own mini Uno on a breadboard — and be able to communicate with it.

Why Even Think About It?

So, you've got a good partnership going with your Uno. Why would you even want to consider making the leap into the unknown? Using my irrigation controller as an example, I'll give you a few good reasons:

Physical Form: The Uno measures 55 mm by 75 mm and is a chunky rectangular shape. In contrast, the microcontroller on the Uno only measures 10 mm by 35 mm, and can be built into a board of almost any shape you want **(Figure 2).**

Figure 3 had a shift register, an EEPROM chip, a real

FIGURE 2. Square peg, round hole: Form factor is a reason to work with raw microcontrollers.

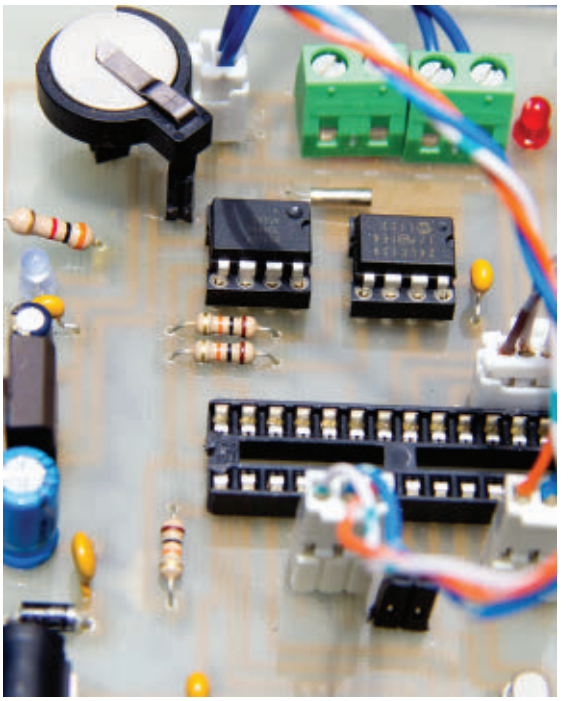


FIGURE 3. Integrating a microcontroller into a PCB with other components.

time clock, an LCD and buttons, and a host of other components. By using a microcontroller, I was able to design and build the whole project on a single printed circuit board (PCB). If I'd gone with an Uno, I would have needed to find a way to mount the Arduino onto my board — or worse, connect it with a whole lot of wires just waiting to come loose.

Cost: There are some low cost Arduino clones available, but they'll be hard-pressed to beat the cost of a microcontroller integrated into your own PCB. The Arduino is great as a prototyping and learning platform, but it just doesn't make sense to have one of these built into every one of your working projects.

Best Tool for the Job: The Arduino range has only a handful of microcontrollers to choose from — and for good reason. However, when I started on one of my smaller sensor projects, having a 28-pin MCU was complete overkill. Instead I opted for a smaller Atmel MCU: an eight-pin ATtiny85.

Additional Flexibility: I recently created a small sensor that I wanted to run on a single battery for at least a year. The design needed to incorporate a slower watch crystal, running at 32.7 kHz. This crystal runs more than 480 times slower than the standard 16 MHz Uno, which translates into a real power savings. I needed flexibility that the Arduino (with a built-in crystal) couldn't offer me.

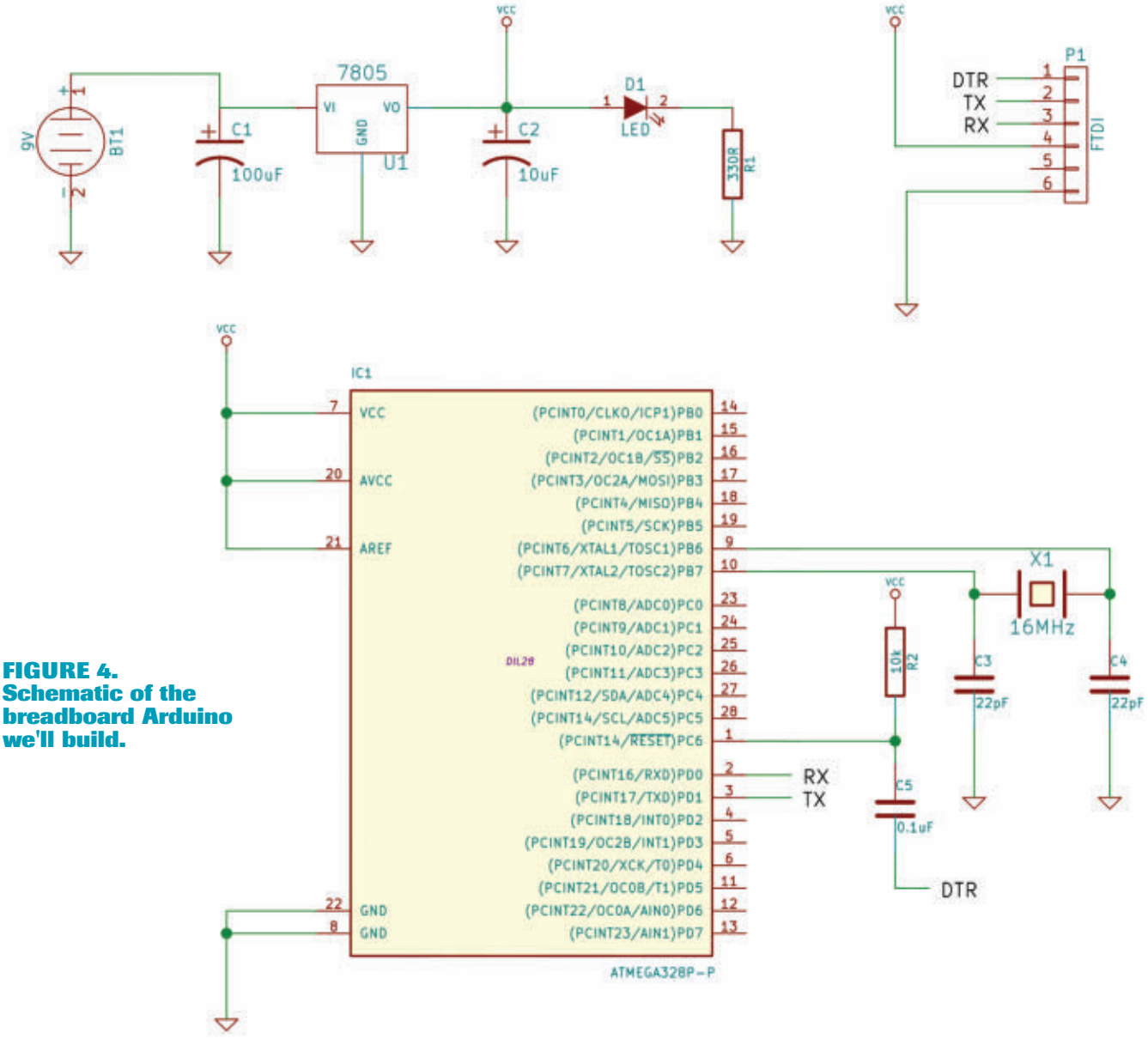


FIGURE 4. Schematic of the breadboard Arduino we'll build.

Voltage Regulators

There are a range of voltage regulators available which can simplistically be divided into switching and linear regulators. We'll work with linear regulators as they are easier to use and need simpler supporting circuitry. When choosing a voltage regulator, the main parameters to normally look at are the dropout voltage, input voltage range, output voltage, and the maximum current.

Dropout Voltage: This shows how much of the input voltage is "lost" within the regulator. It is an important number to look at when considering the voltage that is fed into the regulator. A 5V regulator with 2V dropout voltage needs an input of at least 7V in order to achieve the 5V output. A class of regulators called low-dropout regulators have a lower dropout voltage, meaning firstly that they don't need such a high input voltage, and secondly that they're more efficient.

Input Voltage Range: I normally look at how I'll be powering my project, and then what input range my regulator needs to be able to handle. I'll try to use a voltage source as close to the output voltage as possible (taking dropout voltage into account, of course).

Output Voltage: This is a pretty obvious parameter to look at, but one does need to make a choice whether to go with a fixed voltage or a variable voltage regulator. For our purposes, a fixed 5V regulator does the trick and is simpler to use.

Maximum Current: This is an important number to look at, as regulators can range from as low 20 mA (current that low is not useful for our project). The ATmega328P can supply a maximum of 20 mA per pin (with certain overall limits), so a regulator with a maximum output over 800 mA is more than sufficient. If you want to power other components off your regulator, then it may make sense to get a slightly higher current regulator.

Curiosity and the Challenge: The reasons I've listed so far are all very practical — in fact, they sound a little too practical. So, I think I need to come clean: The biggest motivator for me to start working with microcontrollers was a primeval desire to learn more. I wanted to know *how* that Arduino board worked, and I wanted to build one myself. I was so impressed with the Arduino and what I was achieving, that when I saw I could build my very own I just had to do it. And I haven't looked back since!

Let's Set a Course

Over this series of articles, we'll steer a course from the Uno to working with the raw AVR microcontroller. We'll tackle a number of topics that will enable you to gain greater control (and flexibility) in your projects. The first step is to create a stand-alone microcontroller to work with — essentially, we'll be building our own simplified Uno. For this article, we'll stick with the familiar Arduino IDE, and save the leap to a lower-level development environment for next month.

Build Your Own Arduino Uno

At first, I didn't believe that I could really build my own Uno. The Uno was a mystical blue square of genius — how could a newbie like me create my own? It actually turned out to be less challenging than I thought.

In tackling our simplified Uno here, we'll include only the most important elements: the regulated power supply and the microcontroller itself.

The Microcontroller

The Uno has an ATmega328P-PU microcontroller which is a popular 28-pin MCU from Atmel (see **Resources.txt**). It comes with 32 KB of program memory, 2 KB of RAM, and 1 KB of EEPROM. In the world of computers, this is unbelievably small. However, in the world of microcontrollers, it's a very decent size. We'll see as we progress that some MCUs only have 1 or 2 KB of program memory!

While we're comparing, another big difference to PCs is the speed. The ATmega328P has a top speed of 20 MHz — 150 times slower than a common computer. For microcontrollers, this is a reasonable speed and, in fact, you'll often intentionally slow it down further.

Most microcontrollers need a few simple supporting components to work and the ATmega328P is no different, so we'll include these in the build. The cost? ATmega328P's are readily available from most online electronics stores for less than $4.

Power to the MCU

Microcontrollers are fussy about how they're powered. They need to be fed a constant clean voltage — any ripples, spikes, or variations in the voltages upset their internal workings and could cause them to behave unpredictably. The 5V that an off-the-shelf AC/DC converter (commonly called a wall wart) provides is generally not clean enough for the MCU — and is often not as close to 5V as we'd like. We therefore need to include a regulated power supply on our breadboard.

The ATmega328P can run on a wide range of voltage — from 1.8V up to 5.5V — but we'll stick with the 5V that the Uno runs on.

Less Talk, More Action

Let's get going on the build! Check out the schematic in **Figure 4**.

We're going to start with the power supply first so we have power to test the rest of the board as we build it. I wedged the power supply out of the way on one end of the breadboard, so I had loads of space left to connect other components at a later stage.

The mainstay of the power supply is a voltage regulator. There are a wide range available with different characteristics, but for this project I chose a simple L7805 linear regulator. It's not the most power efficient, but for prototyping it works perfectly (refer to the **sidebar**).

In addition to the voltage regulator, we need a couple of capacitors to help keep the voltage stable — think of a

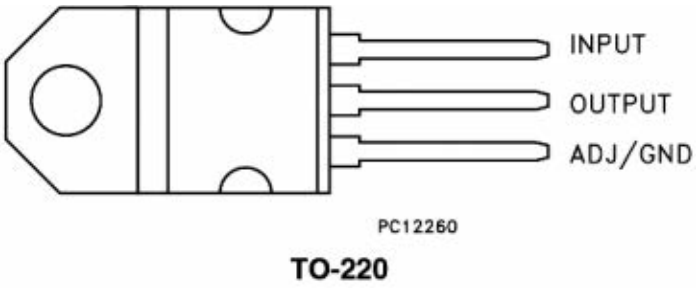


FIGURE 5. Identifying the pins of a voltage regulator from the datasheet.

capacitor as a reservoir that reduces the effect of any spikes or dips in voltage. Finally, we'll add an LED to show when the board is powered up.

A Power Supply in Five Steps

Step 1: Voltage Regulator

Place the voltage regulator on the breadboard in the third row, leaving room for capacitors and leads on either side. You'll need to refer to the datasheet for your particular regulator in order to identify the ground, input, and output pins. **Figure 5** shows a typical example.

Step 2: Power In

Place the leads that you'll connect to your power source in the first row of the breadboard. I soldered a couple of jumpers onto a 9V battery clip, but you could also solder a jack connector that accepts the connector from a wall wart. Make sure that your voltage regulator's input and ground pins are next to each other, and connect the source so that negative goes to ground and positive goes to input.

Step 3: Capacitors

Next, we need capacitors to help maintain a stable voltage. The voltage regulator's datasheet will usually advise on what capacitance these should be in their application circuits. Usually these are polarized, so make sure the leads are connected to GND and V+ correctly. Insert one capacitor on either side of the regulator as shown in **Figure 6**.

Step 4: Regulated Output

We have now created a regulated supply. Insert jumper leads in the same row as the GND and output pins of the regulator, and connect them to the power rails of the breadboard.

Step 5: Turn On the Light

Finally, add an LED and a resistor on the opposite side of the breadboard divider, connecting the LED's anode to the positive power rail, and the cathode to the resistor (which, in turn, connects to the ground rail).

It's now time to test! Connect the input leads to the battery/wall wart and see if the LED lights up. If it doesn't light up, then disconnect immediately and check the connections. I once connected my regulator back to front, and ended up nearly melting my breadboard!

Improving the Power Supply

There are two really useful items that you can add to the power supply to improve it. I haven't added these here in order to maximize breadboard usage and to keep things simple. Firstly, a protection diode: This ensures that nothing gets damaged if you mix up the polarity on your input. After my first mistake with switching the polarity, I learned the value of adding a protection diode between the positive input and the first capacitor.

Secondly, a PTC fuse can be useful to ensure that you don't try to draw too much current through the power supply. A PTC fuse (PolyFuse) is a resettable fuse that trips once its current rating is exceeded, then "resets" once it cools down and allows the current to flow again. I usually place this between my protection diode and the capacitor.

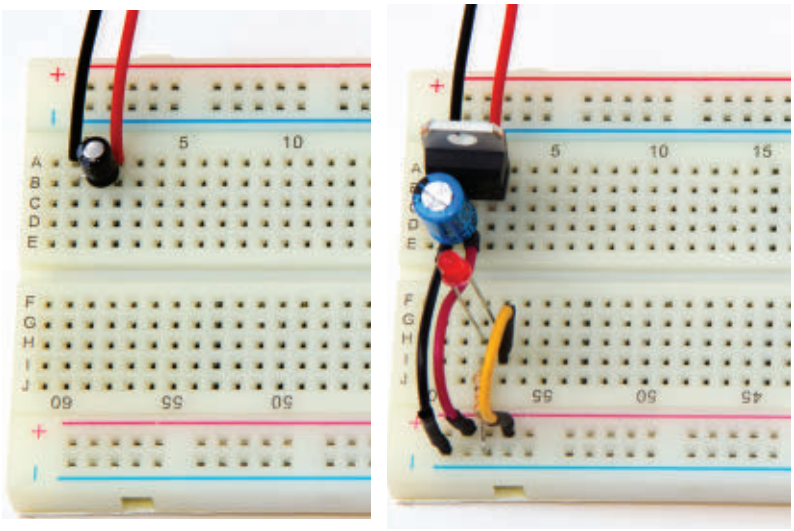


FIGURE 6. Building the regulated power supply on the breadboard.

Bringing the Microcontroller Onboard

Let's bring the microcontroller on board. To ensure compatibility with the Uno, we'll connect an external 16 MHz crystal — in later projects, you'll see this isn't really necessary as the ATmega328P can operate on an internal (slightly less accurate) oscillator. Before continuing, make sure the power is disconnected from the board —

Microcontroller Pin #	Pin Function	Connect to Breadboard Rail
Pin 7	VCC	+ve rail
Pin 20	AVCC	+ve rail
Pin 21	AREF	+ve rail
Pin 8	GND	GND rail
Pin 22	GND	GND rail

Figure 7. Power connections for the ATmega328P.

never connect components when there is power!

Step 1: The Microcontroller

Gently insert the ATmega328P into the breadboard so that it straddles the center separator. Place it so as to keep the board nice and compact. You'll probably need to bend the pins slightly inward as they're normally angled just too wide to fit easily into the breadboard. I place the chip on its side on my anti-static mat, and gently bend them in with a short ruler to keep them aligned.

If you prefer, you can use a ZIFF socket to allow for easy removal and re-insertion. Personally, I don't like this option as the pins in the socket don't always line up nicely with the breadboard pins. Most ICs have a notch in the center of one end and/or a dot/triangular marking at one of the pins — this helps to orient the chip correctly. Pin 1 is always the pin to the left of the notch, or the pin indicated by a dot. If in doubt, check the pin diagrams on the first few pages of the datasheet.

Step 2: Connect the Power

With reference to the datasheet to help in identifying the pins on the microcontroller, connect the MCU pins to the power rails on the breadboard as in **Figure 7**.

Step 3: Connect the Crystal

The Uno has an external 16 MHz crystal to set the speed of the microcontroller. We'll therefore connect one to the microcontroller — we need to connect it to pins 9 and 10.

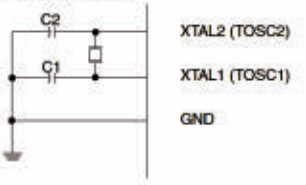
If you've been brave enough, you may have looked at the ATmega328P datasheet (a whopping 567 pages long). I often opened it, skimmed through it, and then closed it in terror. Slowly, I became more comfortable with it, and eventually even started to find it useful.

Once of the things the datasheet states is that the crystal needs to have capacitors connected between the crystal pins and ground. **Figure 8** shows that the recommended range is 12-22 pF — I had some 22 pF ceramic capacitors lying around, so I used those.

Step 4: Stop the Reset

Pin 1 of the ATmega328P is labelled RESET.

Figure 9-2. Crystal Oscillator Connections



The Low Power Oscillator can operate in three different modes, each optimized for a specific frequency range. The operating mode is selected by the fuses CKSEL3...1 as shown in Table 9-3 on page 30.

Table 9-3. Low Power Crystal Oscillator Operating Modes[3]

Frequency Range (MHz)	Recommended Range for Capacitors C1 and C2 (pF)	CKSEL3...1[1]
0.4 - 0.9	–	100[2]
0.9 - 3.0	12 - 22	101
3.0 - 8.0	12 - 22	110
8.0 - 16.0	12 - 22	111

Notes: 1. This is the recommended CKSEL settings for the difference frequency ranges.
2. This option should not be used with crystals, only with ceramic resonators.
3. If the crystal frequency exceeds the specification of the device (depends on V_{CC}), the CKDIV8 Fuse can be programmed in order to divide the internal frequency by 8. It must be ensured that the resulting divided clock meets the frequency specification of the device.

FIGURE 8. Crystal connection specifications from the ATmega328P datasheet.

The line above the pin name means that it is "active low" — in other words, the microcontroller will be in a reset state when the pin is low.

We really don't want the microcontroller to spend its time in reset — it doesn't do anything in this state. Therefore, we need to tie this pin high (to +5V). We could just use a jumper here to connect it to the +ve power rail, but that will interfere with our efforts to program it later.

For now, we need to use a resistor to connect it to the +ve rail; I used a 10K resistor successfully.

Almost There

We're nearly done. **Figure 9** shows the microcontroller we've built that is able to function on a

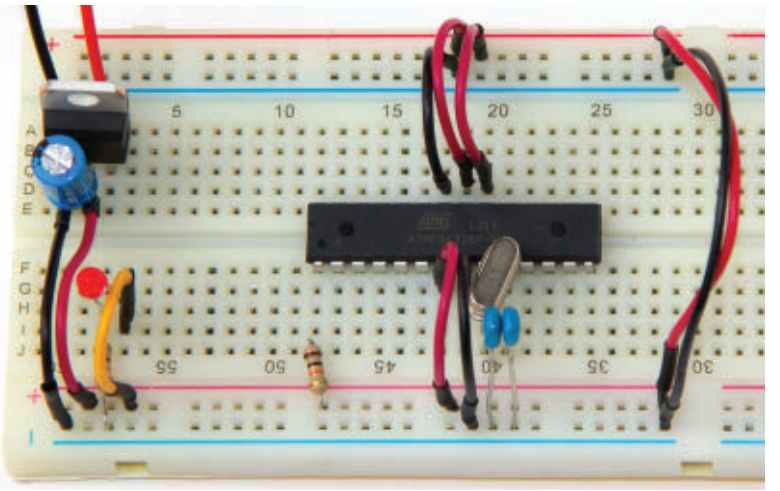


FIGURE 9. An Arduino on a breadboard.

Bootloaders and Serial Communications

"What the heck is a bootloader?" That was my first question as I started on my learning curve to programming stand-alone microcontrollers. In generic terms, a bootloader is a program that runs when a PC or microcontroller starts up. In the world of microcontrollers, the function of the bootloader is to transfer a sketch (over the serial port) onto it.

If no sketch is available to be transferred over the serial port, then the bootloader transfers execution to the sketch currently loaded on the microcontroller.

What this means to you and me is that we're able to upload sketches to a microcontroller without needing a dedicated hardware programmer — all we need is a way to allow the PC to communicate serially with the MCU. For that, we'll use a USB-to-serial converter — the most common being an FTDI cable or board that works great for programming microcontrollers.

Resources

Author's Website:
www.crash-bang.com

Atmel ATmega328P:
www.atmel.com/devices/ATMEGA328P.aspx

SparkFun's FTDI Breakout Board:
www.sparkfun.com/products/9716

stand-alone basis — this is all you need to deploy a project into the "wild." When I built my first one, I couldn't believe that this was all I needed to get a microcontroller project up and running. Of course, we need to be able to program the MCU, so these final few steps will get that working.

Open Channels of Communication

When I tackled my first breadboard Uno, I underestimated the challenges involved in being able to talk to it. It took a fair amount of research, twiddling, and hair pulling (which unfortunately, I can ill afford!) to get the right components in place to program my project. I was using an ATmega328P-PU loaded with the Optiboot bootloader — the same configuration as the Uno. The bootloader (refer to the **sidebar**) allows us to program the MCU over a serial connection .

The first USB-serial converter I bought was an FTDI basic breakout board from SparkFun (see **Resources.txt**). It was also the last one I bought — not because it was bad, but because it's given me all that I've needed over the past few years.

The FTDI board has five pins that need to be connected in order to get it working.

Pin 1: Reset

Before we start uploading a sketch to the microcontroller, we need to reset it in order to fire up the bootloader. The FTDI board sends a "low" signal over the "DTR" pin before it starts transmission. Therefore, we need to connect this to the RESET pin on the ATmega328P. The low pulse "overpowers" the 10K pull-up resistor on the RESET pin and causes the microcontroller to enter the reset state.

One of the problems I encountered was the range of opinions on whether or not a capacitor is needed on the reset line. On my first attempt, I couldn't get the microcontroller to enter a reset state and accept the sketch being uploaded. When I added a 0.1 µF capacitor, the programming worked perfectly. The Atmel design notes state that they aren't required, but can filter out noise. In your build, test it out and see what works best.

Pins 2 and 3: Tx and Rx

As any corporate coach (or marriage counselor, for that matter) will tell you, communication is a two-way process. The same applies to the microcontroller — it needs to receive (RXD) and to transmit (TXD). It makes sense that the *transmission* of one party is *received* by the other. Therefore, we connect the TXO pin of the FTDI board to the RXD pin (pin 2) of the microcontroller, and the RXI pin of the FTDI to the TXD pin (pin 3) of the microcontroller.

These are often connected incorrectly, which is why SparkFun added an "O" to the Tx pin (to specify output) and an "I" to the Rx pin (to specify input).

Pin 4: GND

This is straightforward — connect the GND pin from the FTDI to the GND rail on the breadboard. Regardless of whether you choose to power the board from the FTDI board, you still need to connect the GND.

Pin 5: Power

If you want to power your MCU from the FTDI board (I often do), then connect the 5V pin (or the 3V3 pin, depending on the model you have) to the +ve power rail.

We're Finally There

We're done with the wiring now — we have a fully functioning (simplified) Arduino on a breadboard (**Figure 10**)!

When I completed this for the first time, I couldn't wait to test it out. So, of course, I uploaded the "Hello World" of microcontrollers: a sketch that blinks an LED.

The great thing about having created a project that is effectively Arduino compatible was that I could use the Arduino IDE to upload a sketch. I could take things step by step rather than jumping off a precipice!

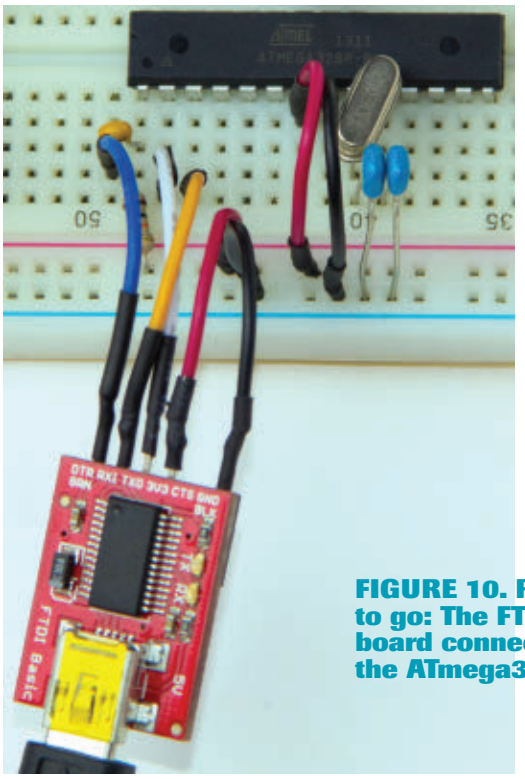


FIGURE 10. Ready to go: The FTDI board connected to the ATmega328P.

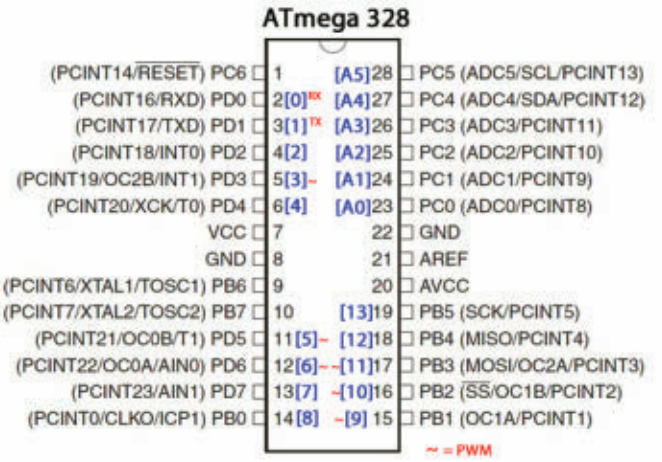


FIGURE 11. Mapping the Arduino pin numbers with the ATmega328P pins.

Make that LED Go "Blink"

I'm sure you've made your Arduino blink an LED before, probably using the example sketch — the built-in LED on pin 13. Of course, on this board we don't have an LED on pin 13 — so let's add one.

At this point, I learned one of the most important lessons of my transition away from the Arduino: Pin 13 on the microcontroller is not the same as the pin labelled "13" on the Uno. I connected my LED to pin 13 on the microcontroller, fired up the sketch, and ... nothing. Not a flicker. A whole lot of research later, I found that "13" isn't always "13" — unlucky!

The datasheet on the ATmega328P labels the function of the pins pretty cryptically, so I created a quick cheat sheet to work off of in my projects (**Figure 11**). This "maps" the actual pin numbers on the ATmega328P (which you'll see run sequentially around the chip) to the Uno pin numbers (in square brackets).

From this, we can see that the Uno's pin 13 is actually the microcontroller's pin 19. Carefully count your way around to pin 19, and then connect your LED as you

Parts List

ITEM	DESCRIPTION
BT1	7V+ Battery with Clip and Leads
C1	100 µF 16V+ Aluminium Electrolytic Capacitor
C2	10 µF 16V+ Aluminium Electrolytic Capacitor
C3	22 pF Ceramic Capacitor
C4	22 pF Ceramic Capacitor
C5	0.1 µF Ceramic Capacitor
U1	Linear Voltage Regulator 5V (e.g., L7805/LD1085V50)
D1	Red LED 20 mA
R1	330 ohm Resistor, 0.25W
R2	10K ohm Resistor, 0.25W
X1	16 MHz Crystal
IC1	ATmega328P-PU Microcontroller

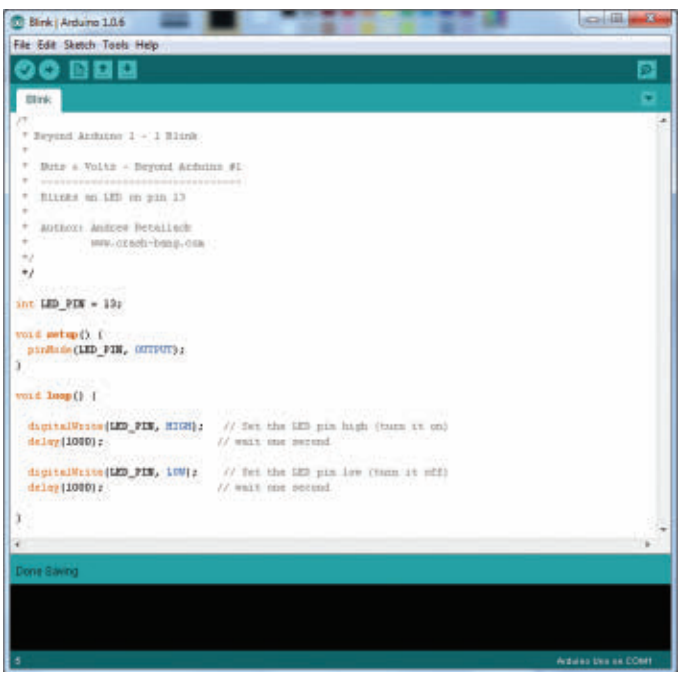


FIGURE 12. The Arduino blink sketch to upload.

Listing 1

```
/*
 * Beyond Arduino 1 - 1 Blink
 *
 *  Nuts & Volts - Beyond Arduino #1
 *  --------------------------------
 *  Blinks an LED on pin 13
 *
 *  Author: Andrew Retallack
 *          www.crash-bang.com
 */
 */

int LED_PIN = 13;

void setup() {
  pinMode(LED_PIN, OUTPUT);
}

void loop() {

  digitalWrite(LED_PIN, HIGH);      // Set the LED pin high (turn it on)
  delay(1000);                      // wait one second

  digitalWrite(LED_PIN, LOW);       // Set the LED pin low (turn it off)
  delay(1000);                      // wait one second

}
```

normally would on an Arduino project: anode to pin 19; cathode to resistor; and resistor to the GND rail.

Load the blink sketch up (**Figure 12**) and select the Uno as your board. I usually check what serial ports are available under the "Serial Port" menu and make a note of them. I then plug my FTDI cable or board in and give the PC enough time to recognize it (by now, you'll have realized that I'm working on a Windows machine). I take another look at the Serial Port menu and choose the new port that has appeared.

Before you do this, you will need to have installed the drivers that the FTDI manufacturer provides. I sometimes find that Windows doesn't recognize the port, but usually it picks it up if I unplug, wait 20 seconds or so, and then connect the USB cable again.

Once the serial port and board are correctly selected, it's as simple as uploading a sketch to your regular Arduino. Click the upload button and watch the LED come to life!

What's Next?

Looking back on my first foray into microcontrollers, I couldn't wait to build my next design. I spent a whole lot of time working in the Arduino IDE, and coming up with all sorts of projects. I went down the path of etching my own circuit boards and incorporating this basic microcontroller setup into my builds.

After a while, I wanted to work on more complex projects that demanded more from the microcontroller. The trigger was trying to reduce the power consumption on one of my projects — when I looked at some of the online projects around, I realized that I had a lot more exploring and learning to do!

My first step was to say goodbye to the Arduino IDE and step up to the more fully-featured (and more complex) Atmel Studio (Atmel's own in-house IDE). In moving onto Atmel Studio, I had to understand the microcontroller from a very different perspective and learn how to use it quite differently. In my next article, we'll start a journey in that same direction.

Make sure you keep your breadboard Uno handy, as we're going to be using it next time, and through the rest of this series. **NV**

 Continued from page 7

display will show. However, it should work lower, with some caveats. Your question does bring up a very important point that needs to be addressed.

The ratings listed in datasheets are those that the component was designed for and tested to. If a part fails prior to reaching its maximum rating, then it is defective and – depending on return policies – should be replaced.

Fortunately, many components don't fail abruptly. They tend to deviate from their normal function. So, I expect my thermometer will need an adjustment to its calculated temperature as its gets colder. This can be done with software, so it's trivial to fix.

My flight computers and sensors produce output that changes gradually during a flight. Since I don't see an abrupt change in sensor output, I know there's no significant failure. There may still be calibration issues to deal with, but I expect they're minor.

Paul Verhage

Power to the USB

Thanks for the January 2015 PICAXE Primer column, even though I don't use PICAXE. It was an interesting look at USB that I've not looked into before. Out of curiosity, is there not a need to include any filtering caps on the supply? I'm sure that the supply from a PC is relatively clean, but what about the wall wart?

Andrew Retallack

I'm glad you found the January Primer article interesting, Andrew!

Your email prompted me to pull out my scope and run three separate tests. I connected a USB cable to the following three voltage sources, and took a look at the +5V power line in each case:

1. A USB port on my PC.
2. A powered USB hub.
3. A 5V (1A) USB wall wart.

To place a load on the supply, I connected a 1K resistor between +V and ground on the breadboard. As expected, the output voltage did vary slightly among the three power sources (from 5.2V to 5.4V), but otherwise, all three sources produced essentially the same result: There was a small high frequency ripple (about 18 mA @ 20 MHz).

I have been using an FTDI USB-to-serial cable for powering and

Continued on page 81

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Give Your Sound a Boost — Amplifier Modules to Power Your Project's Audio

Sound is important! If it's working well, it fades into the background, but noisy (or quiet) audio can spoil nearly any project that's supposed to make sounds. From custom boomboxes to special effects and robotics, what good is your project if nobody can hear it? It's easy to throw in an LM386 while working on the bench, but to take your project out of the lab you're going to need more than the little chip's one watt or so of output power.

Unless you're specifically building an audio amplifier, most of the time it's easier to just go with a drop-in solution so you can focus on the rest of project. There's quite a few modules on the market, with all the components assembled and ready to provide that much-needed boost in power to your project's audio output. Just supply an audio signal and go!

Parts Express provided a selection of low to mid power amplifier modules to evaluate for this article, which are perfect for including in a larger design (**Photo 1**). These three modules are available at **Parts-Express.com**, and all run from a 12V DC power supply. There's a Diodes

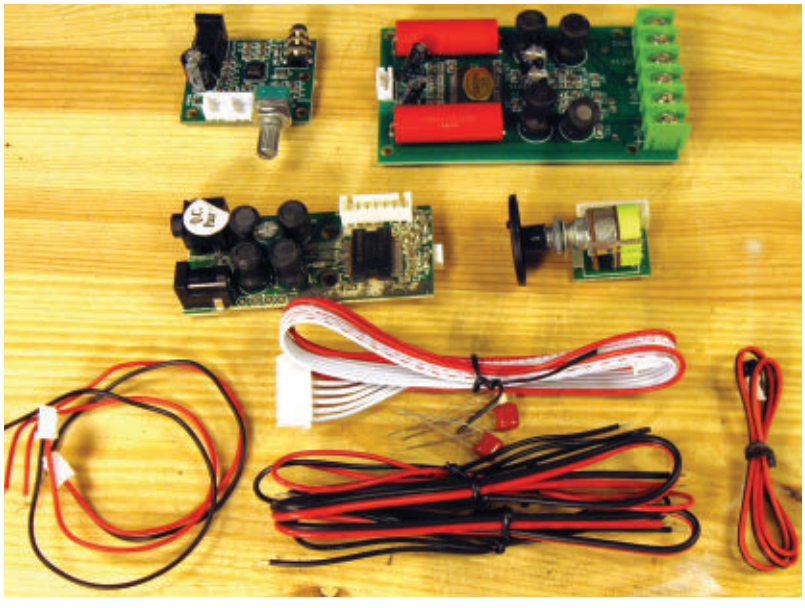


PHOTO 1. The three modules and their accessories. Top left, the PAM8610. Top right, the model TA2024 board. Everything else: the DTA-2 digital audio amplifier module.

Post comments on this article at **www.nutsvolts.com/index.php?/magazine/article/march2015_Koebel**.

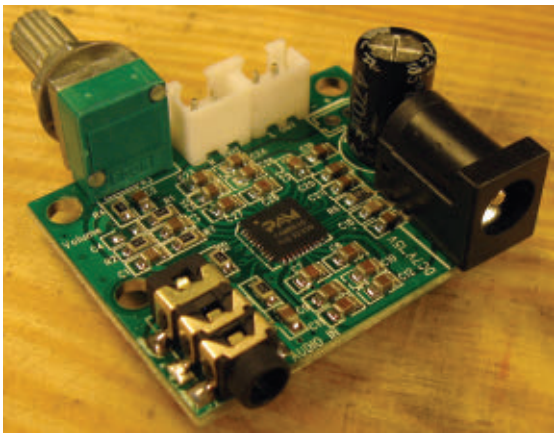


PHOTO 2. The PAM8610 amplifier module, with its all surface-mount construction.

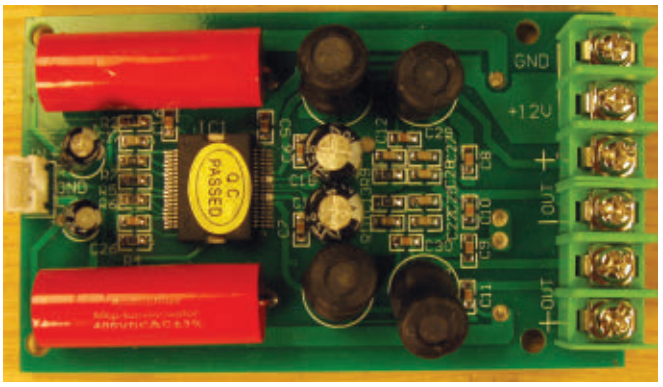


PHOTO 3. The model TA2024 amplifier module.

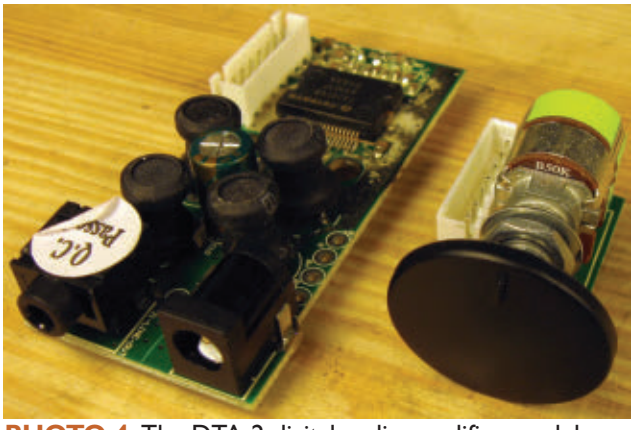


PHOTO 4. The DTA-2 digital audio amplifier module.

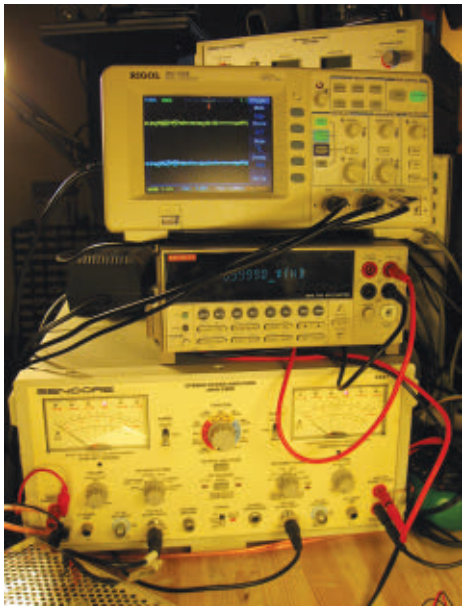


PHOTO 5. My test stack: Top, Rigol DS1102E digital oscilloscope; middle, Keithley 2015 THD multimeter; bottom, Sencore PA81 stereo power amplifier analyzer.

Incorporated PAM8610-based class D amplifier module offering up to 10W RMS in a package just a little bigger than a quarter (**Photo 2**). Next, there's a pair of amplifiers based on the Tripath TA2024 "class T" amplifier chip: the model TA2024 board shown in **Photo 3**; and the Dayton Audio DTA-2 digital audio amplifier module shown in **Photo 4**. Both these boards deliver up to 15W RMS output power.

The smallest option (the PAM8610) has a completely integrated tiny package which makes it great for any place space is a factor — like wearables or ultra-portable accessories. The Dayton Audio DTA-2 has flexible mounting options with a two-board design connected by a ribbon cable and with all the controls onboard, but does require four solder connections to assemble it.

Lastly, the model TA2024 comes with no onboard controls at all — just a three-pin connector and screw terminals which would work well in a system with an external volume control, or where the signal level is controlled by another active device like a microcontroller or single-board computer.

PAM8610 2x10 Class D Audio Amplifier Board
$11.80

T-Amp Tripath TA2024 2x15W Audio Digital Amplifier Board
$13.80

Dayton Audio DTA-2 Class T Digital Audio Amplifier Module
$19.80

The Test Setup

In addition to hooking them up for a listen, I measured each of these amplifier modules with a Keithley 2015 THD multimeter using its internal source as the signal generator, and a Sencore PA81 stereo power amplifier analyzer for output meters and load resistors (**Photo 5**). The pulse output from the generator served as the external trigger control for the Rigol DS1102E digital oscilloscope to keep an eye on the waveforms during testing. I powered the modules with a 12V 10A regulated switching power supply (**Photo 6**).

All of these modules are primarily designed to power a four ohm load, but are generally happy with eight ohm

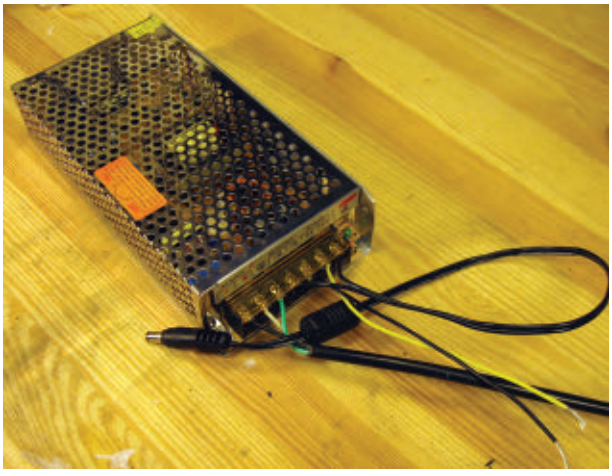


PHOTO 6. A generic but high quality 12V 10A regulated switching power supply used to power the modules.

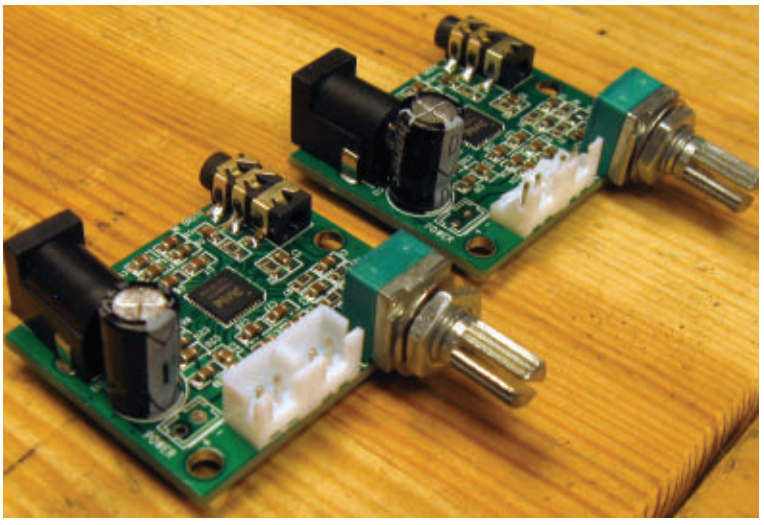


PHOTO 7. Both PAM8610 modules performed very similarly.

loads, as well. So, I took THD+N measurements using both. All the tests were performed at an ambient temperature of 20°C (the temperature in my shop), which is a bit lower than the 25°C ambient temperature for measurements in the chip datasheet. If anything, these amplifiers might perform a little better at a slightly lower temperature (**Photo 7**).

Smallest First

As mentioned, the smallest of the amplifier modules is the PAM8610. Since it's just a little bigger than a quarter, it could fit nearly anywhere. According to the datasheet, with a 12V power supply the chip can deliver up to 10W at very low distortion, and 15W at 10% THD+N when fitted with a heatsink; refer to **Photo 8**.

The tiny module looks to be fairly close to the reference circuit provided by the manufacturer (**Photo 9**).

Except for the onboard filter capacitor, control, and input/output connectors, the module is entirely surface-mount construction, with entirely 0805 components and the QFN amplifier chip. This particular module uses a DC volume control, so it's only a single potentiometer instead of the dual control used in the signal path of the Dayton Audio DTA-2 module, which saves some space. It's small enough that it could feasibly be integrated with a project like Craig Lindley's DIY electric guitar to make a self-powered/self-amplified musical instrument. That'd be pretty interesting to see! (Refer to **Photo 10**.) It's very

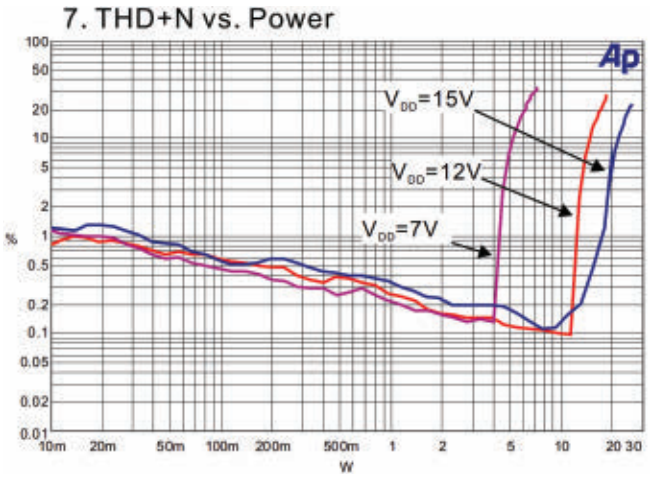


PHOTO 8. THD+N vs. power for the PAM8610 chip, from the manufacturer's datasheet.

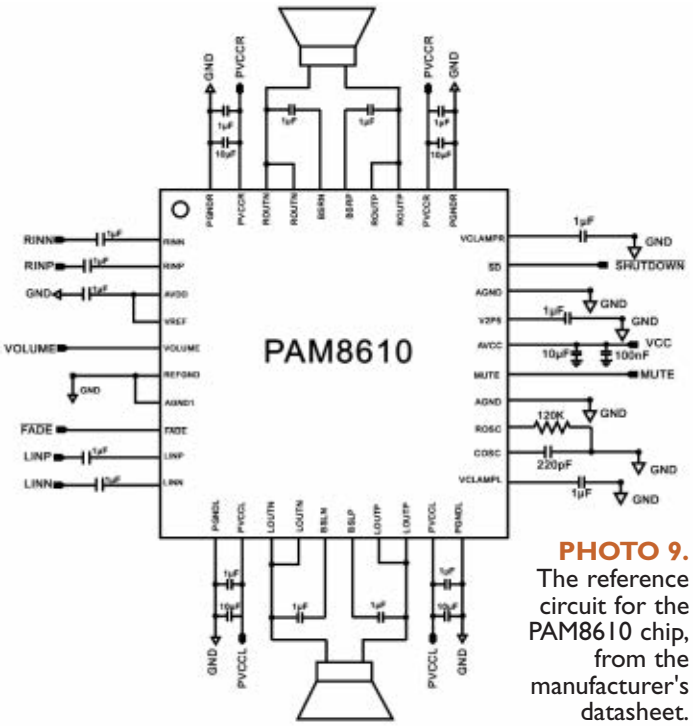


PHOTO 9. The reference circuit for the PAM8610 chip, from the manufacturer's datasheet.

inexpensive, too, at only a little over $10.

On my first run through testing this module, I was so surprised by the performance I measured that I reached out to Jill (my contact at Parts Express) to get some more information. It looked downright broken!

My initial measurements were showing no less than 9.1% THD+N at low power, rising very quickly to more than 60% THD+N. That can't be right! Jill put me in touch with Rory, the Product Line Manager for these modules over at Parts Express, who sent me a note about the test strategy for this type of device. He grabbed one off the shelf and took some of his own measurements to confirm my findings.

PHOTO 10. Craig A. Lindley's electric guitar project (*Nuts & Volts*, June 2013).

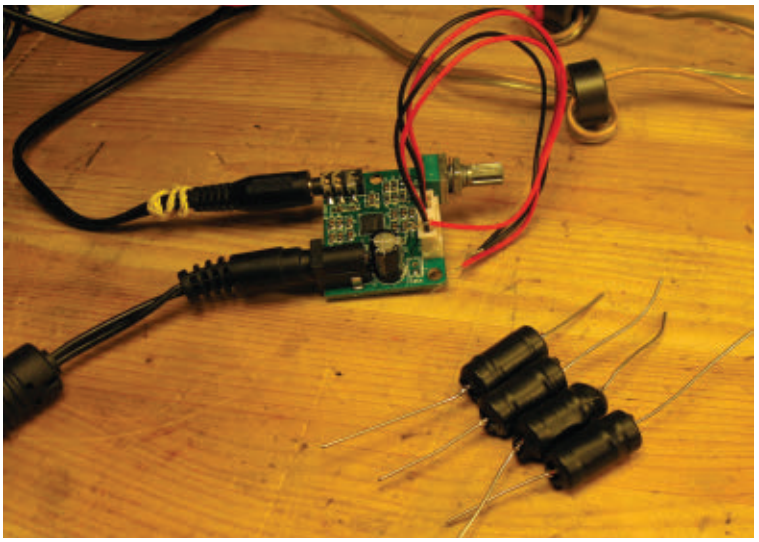


PHOTO 11. The PAM8610 next to the 50 uH low DC resistance inductors to simulate the speaker load.

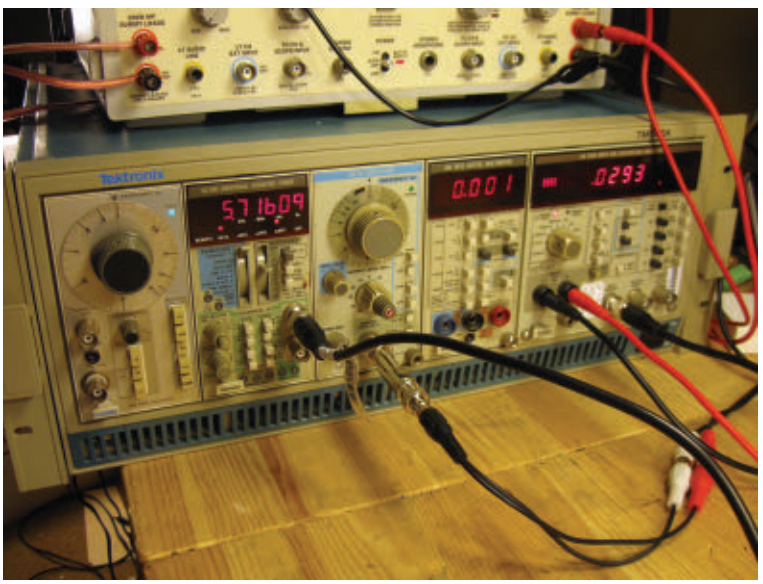


PHOTO 12. Tektronix TM504A mainframe housing the AA 501A audio analysis system.

Rory wrote, "*Most stand-alone class D amps provide onboard reconstruction filtering, but amp boards designed to be built into a device will sometimes omit it because they intend for the driver VC inductance to take care of the needed filtering. The PAM8610 board we sell is one of this type.*"

That's true. There is no filter on the output of this module. Rory and I had a short phone conversation where he explained his own test setup, and recommended I limit the bandwidth of my THD analyzer to keep residual switching noise from impacting the measurements. He also suggested adding a series inductor in each leg of the speaker leads to simulate the inductance of a voice coil (which wasn't provided) into a resistive dummy load. He checked a few speaker datasheets, and we determined that 50 uH in each leg should accurately simulate a speaker driver load. Armed with this information and several low DCR chokes, I went to try again; refer to **Photo 11**.

The second time measuring this module, I switched to my other audio analysis system which has better filter options (a Tektronix AA 501A Mod WQ distortion analyzer with SG 505 ultra-low distortion oscillator) and re-ran the numbers with a 30 kHz low pass enabled, along with the inductors in each leg of the speaker leads (**Photo 12**). This seemed to do the trick since performance improved drastically! It no longer seemed to be completely broken, although it was still coming in a bit

A class D amplifier — or switching amplifier — differs from most other types of amplifiers in that instead of directly amplifying a signal, it uses high speed pulse width modulation (PWM) followed by a low pass filter to recover the analog waveform from the pulse train. These amplifiers are very efficient, but can be challenging to design and implement. Class D amplifiers commonly use a switching frequency around 10x the highest frequency of the signal to be amplified, such as the PAM8610 with a 250 kHz switching frequency to deliver full audio bandwidth. A "class T" amplifier is the name for Tripath's proprietary implementation of class D technology, which uses an advanced control scheme and an extremely high switching frequency (50 MHz or greater) to deliver even higher efficiency and performance.

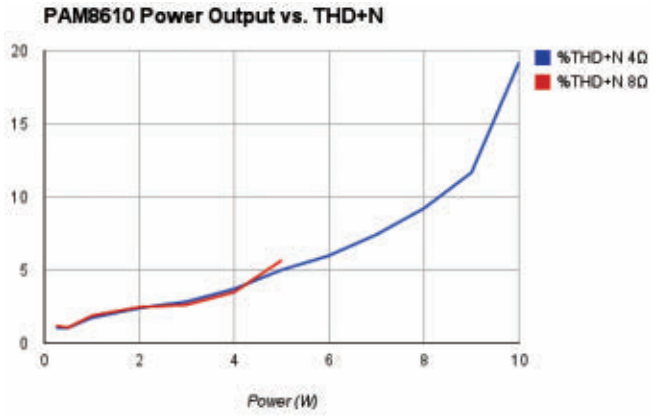


PHOTO 13. PAM8610 THD+N measured into four and eight ohm loads from 0.25W through maximum power output.

higher than the theoretical specs say it should. However, at such a low price ($11.80), it's easy to imagine there were some design trade-offs to keep the price down while still delivering reasonable audio quality.

In total, the distortion started just over 1% THD+N at 0.25W into any load and rose to over 10% THD+N at about 9W, capping out at a total of 19.2% THD+N into a four ohm load at a maximum output of 10W. Oddly, neither sample of this module I was sent would deliver above 5W into an eight ohm load. I did experience some odd cut-in/cut-out behavior at bass frequencies and when running it very hard; Rory mentioned he'd encountered similar behavior on our call.

We determined it occurs when the amplifier exhausts its current reserve in the onboard electrolytic capacitor. It would be pretty easy to change out the stock 470 µF capacitor for a much larger one to improve the low end performance (**Photo 13**).

My live listening test confirmed what the meter measured: a fair amount of background hiss, although not too bad at low volume; and distortion growing quickly but still delivering quite an intelligible signal.

Due to the noise and distortion on this module, I couldn't recommend it for a hi-fi musical application, but in a project where audio quality isn't a huge factor it could certainly get the job done. Guitar amplifiers often have a fairly high distortion figure anyway, so the self-powered guitar project is still on the table. Other applications where you need some volume but won't be playing much recorded music would also be great — maybe a DIY intercom or pager project, or built into a small kiosk or pop-up display to play interface noises and sound effects.

Several forum posts on diyAudio and other Web communities also report similar performance with modules based on this chip, and speculate that performance might be improved by swapping out some of the surface-mount components for other values and adding better cooling.

If you're into experimenting, it might be a fun exercise to get this little module to perform better. The price is low enough it wouldn't break the bank to try. The underlying chip has great specs, so if you've got a set of hot tweezers and don't mind working under a magnifying glass, modifying the module would probably be an interesting project unto itself.

Headers Only

Moving up a bit, the model TA2024 amplifier module (its stock number happens to be the same as the chip) takes up quite a bit more space, but really does offer a lot of flexibility — all that extra space means bigger, better components. There are a set of film input capacitors, plus an actual sharp-cutoff low pass filter on the output to remove any residual RF left over after the switching.

The module comes with a small three-conductor cable

PHOTO 14. The back of the Wi-Fi Internet radio project showing an amplifier module (*Nuts & Volts*, March 2012).

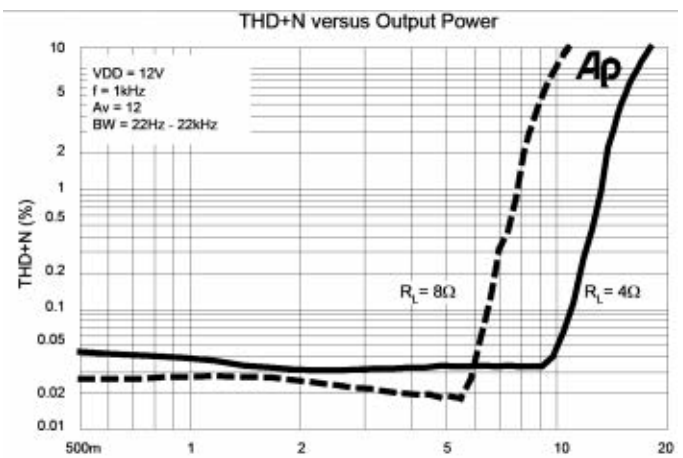


PHOTO 15. THD+N vs. power for the Tripath TA2024 chip, from the manufacturer's datasheet.

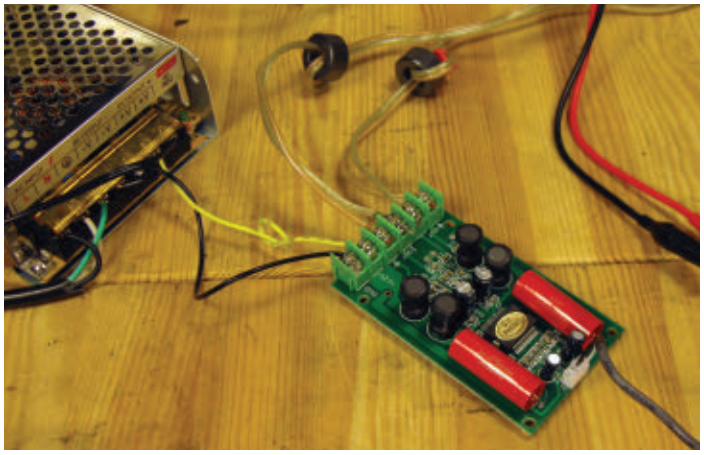


PHOTO 16. The model TA2024 amplifier module under test.

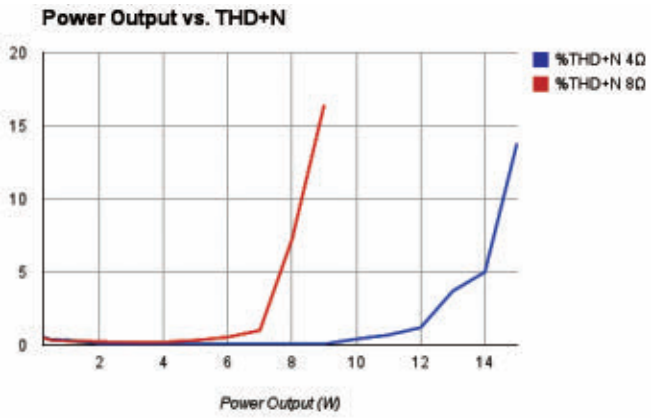


PHOTO 17. Model TA2024 THD+N measured into four and eight ohm loads from 0.25W through maximum power output.

for the inputs and attaches to a socket on the left side of the board; on the other side is a barrier strip with screw terminals for the left and right speaker outputs and power supply connection. That's one of my favorite things about this module since it will make it so easy to integrate it into other projects with a minimum of messing around with external controls and switches. It'd be easy to attach a volume control pot to the input if needed, but I'm envisioning this one being great in applications where the audio signal is being controlled by a pre-amp or receiver — like the Wi-Fi Internet radio project shown in **Photo 14**.

The Tripath TA2024 is a decent little chip itself. It can deliver up to 15W into a four ohm load at 10% THD+N, but is rated for "audiophile" quality sound at up to 9W at 0.04% THD+N (**Photo 15**). Naturally, this is going to depend on the implementation, which can really throw it off if it's done poorly. Fortunately, though, this module delivers pretty close to its specified performance. It's close to the reference design from the datasheet, as well (**Photo 16**, **Photo 17**, and **Photo 18**).

I'd call this a very solid implementation; performance is very close to the datasheet figures. While everyone's ears are a little different, most people can't pick out distortion below about 1% unless they're specifically looking for it. This module delivered 11W into a four ohm load at only 0.7% THD+N. At 9W, it was well into the audiophile quality range, with only 0.082% THD+N — a bit higher than the theoretical figure of 0.04% THD+N, but very respectable nonetheless. This is a good little board!

One thing about this particular module ... it only delivered the low distortion into a four ohm load. It's rated for much less power into an eight ohm load, but comparing performance at 5W, the module delivered 0.55% THD+N which is much higher. Certainly listenable,

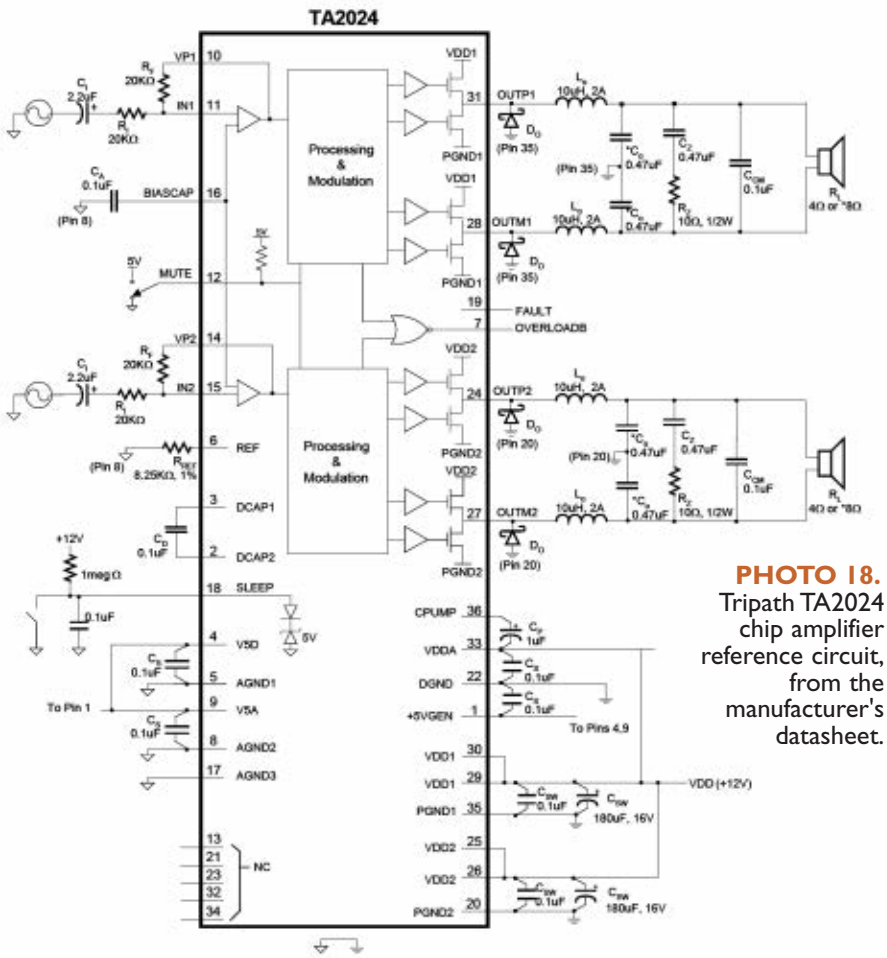


PHOTO 18. Tripath TA2024 chip amplifier reference circuit, from the manufacturer's datasheet.

PHOTO 19. The Big Ear distant listening device to pick up sounds from far away (*Nuts & Volts*, December 2008).

but getting up into the range where I might not consider it audiophile quality.

The sound itself was clean and neutral through the middle of the range (if a bit thin sounding), and not unpleasant or fatiguing at all. At the high end of the power output, though, a noticeable hiss came up from the background and the distortion became quite apparent. The audio was still very intelligible, however.

One thing about this module is that it would definitely benefit from a heatsink. After about five minutes playing at the full rated volume, a whisp of smoke arose from the QA sticker which was on the top of the chip. The thermal cut-off killed the output. I think in a real world application, it's unlikely to be run deep into the red the entire time, so I don't see this as a huge problem.

Smoke coming from electronics is never a fun sight, but there was no actual damage. It fired right back up after cooling off, and its performance was unchanged.

The chip is large enough that it would be easy to fit with a heatsink for better thermal performance, and that would almost certainly solve the problem. If you're mounting this in a small enclosure without much ventilation, it'd be a very good idea to include one.

I'd recommend this module for any application that might actually play back music based on its good performance, or where picking out fine details of the sound over speakers might be important; for example, in something like the Big Ear project referred to in **Photo 19**.

PHOTO 20. The DTA-2 digital audio amplifier module with all of its pieces.

A Flexible, Full Stack Solution

The second of the TA2024-based amplifier modules is the Dayton Audio DTA-2 digital audio version. This one goes the opposite direction of the bare board: It has a power connector (although there are solder pads for a hard-wired power supply); a 1.8" stereo mini jack for the input signal; and a volume knob with an integrated power switch on a second small printed circuit board (PCB) connected by a flexible ribbon cable (**Photo 20**).

There's also an LED power indicator which I didn't assemble for these tests. The speaker leads need to be soldered to the board which is a little annoying, but not

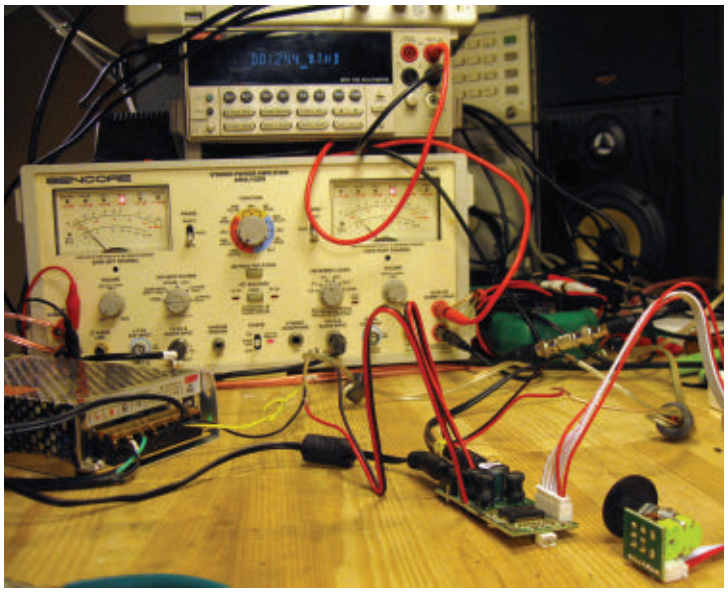


PHOTO 21. The DTA-2 under test.

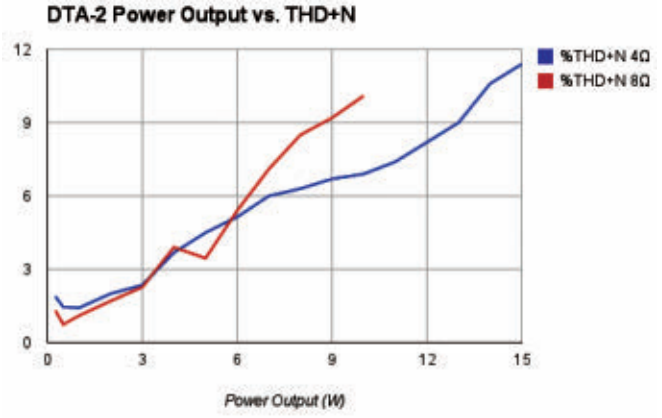


PHOTO 22. Dayton Audio DTA-2 measured into four and eight ohm loads from 0.25W through maximum power output.

PHOTO 23. The Dungeon Keeper — an animated Halloween prop which would go well with some powerful sound effects (*Nuts & Volts*, September 2009).

the end of the world. There are holes for power leads for a hard-wired application in parallel with the power jack, too.

At first glance, this one looks like it should dissipate heat a bit better than the other TA2024 module. There's a large thermal pad on the bottom of the board — even some traces on the top are designed for dissipating additional heat — but it only has one onboard filter capacitor; the rest of the components (except for the output filter inductors) are all surface-mount (**Photo 21**).

Since it's based on the same chip as the other TA2024 module, it will have the same maximum ratings. This one didn't quite measure all the way up to spec, but I'd be comfortable recommending it for more ambient applications where volume and packaging are more important than sound quality.

Distortion rises steadily — although not too quickly — up to 11.4% THD+N at full rated power into a four ohm load, but through much of the range there's little to no background hiss which makes the sound much cleaner overall (**Photo 22**). That's right where the datasheet says it should be in the end, although it is supposed to be mostly clean and flat until the high end of its power bandwidth.

Like its connector-less cousin, this one also went into cutoff when running at high power for several minutes, but since that's not really likely to happen in most real world applications, it isn't a huge problem. Again, a heatsink should clear that right up. It doesn't sound terrible, but at higher power there's a bit of hiss and the several percent distortion is easy to notice.

Since the Dayton Audio DTA-2 doesn't quite manage audiophile-quality sound but is still very listenable, I'd recommend this one for projects where music isn't the main focus, but you might still want to play music on occasion and have it be enjoyable. It would also be great for public address (PA) applications, like haunted house Halloween projects such as the ones in **Photo 23** and **Photo 24.** If you're playing spooky sine waves or monster screams, it doesn't need to be super clear as much as it needs to be loud.

The flexible mounting options (the on-off/volume control is able to be mounted separately from the amplifier itself) mean this could fit into a variety of enclosures, too — even with both boards, the footprint is considerably smaller than the other TA2024, so it could do well where audio was something of an afterthought. It might also make a good outdoor Bluetooth speaker set where you wouldn't be able to notice the distortion as much.

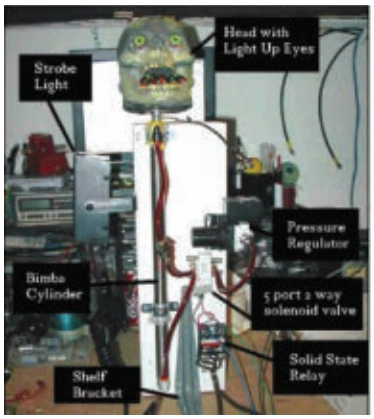


PHOTO 24. The Prop Dropper — a spooky Halloween project which certainly could use a punch in the audio for ambient effects (*Nuts & Volts*, October 2009).

Final Thoughts

Designing your own amp can be a fun project, but in most cases where you need some volume but don't much care about the specifics, a module like one of these is the way to go. Based on my results, any of these modules has good potential for a variety of different applications. The PAM8610 would shine in lower powered, non-musical projects where size is a factor. The model TA2024 amplifier module and the Dayton Audio DTA-2 digital version (both based on the Tripath TA2024 class T amp chip) do a great job and provide more power at lower distortion.

If you're building a project that's primarily musical, I'd recommend the model TA2024 on account of its audiophile-grade performance. For hybrid applications like sound effects or where you don't quite care about the sound (like a DIY Bluetooth speaker project), I'd recommend the Dayton Audio DTA-2 digital audio amplifier module.

All of these modules are quite efficient and would be easily powered by a lead-acid battery. Or, you could add a switching boost converter if you have a smaller project that's powered by some LiPo cells or other batteries with a lower voltage but high power density. If you're like me, you probably have a few 12V mains power supplies lying around already. An old computer power supply or even discarded wall warts could easily power any of these modules for your next built-in project.

The modules I've covered here will also integrate easily into an existing project, which is part of what makes them a good bargain. You can unlock your gadget's audio potential. Happy hacking! **NV**

A Look at the 23rd Annual "Last" Chicago CoCoFEST!

The 23rd annual "Last" Chicago CoCoFEST! was held April 24-25, 2014 to celebrate RadioShack's TRS-80 Color Computer — a personal computer that was popular in the '80s. So, why am I writing about a vintage computer expo in this modern world of Windows, Androids, and iPads? Because this fest not only highlights the Color Computer, but also showcases a fusion of old and new technology. Instead of tossing the old aside, the people that make up the Color Computer community take cutting-edge technology and use it to enhance and rebuild the TRS-80.

By Salvador Garcia

Post comments on this article at **www.nutsvolts.com/index.php?/magazine/article/march2015_Garcia**.

Why is a '80s Computer Still Relevant?

With Mac OS, Linux, and Windows dominating PCs today, anyone can ask why the Color Computer (or, CoCo for short) would be relevant. After all, we are talking about a computer that existed in an official capacity from approximately 1980 to 1991, whose stated maximum RAM capacity was 512 Kb with a maximum processor speed of around 2 MHz. Today's computers — with advanced processors from Intel and AMD, plus gigabytes of RAM and storage capacity — tower over the Color Computer's meager specs.

Still, when the Color Computer first debuted it was one of the most innovative PCs of its class. This new entry into the home computer fray was based around the Motorola 6809 microprocessor. The processor's lineage could be traced back to the PDP line of mini computers made by Digital Equipment Corporation. The 6809's architecture, instruction set, and addressing schemes were based on the PDP's own.

This characteristic alone made the 6809 one of the more advanced microprocessors of its time as compared to others such as the MOS 6502 and the Zilog Z80 — perhaps the two most commonly used processors in home computers. In 1980, when the TRS-80 debuted using this processor, it was a big deal. It is thanks to innovative technology such as the 6809 that we have the powerful systems that we use today.

Let me share with you some of the exhibitors that were present at last year's CoCoFEST!

Cloud-9

Cloud-9 (**www.cloud9tech.com**) is a company that was founded in 1994 by Mark Marlette, and provides hardware and software for the three versions of the Color Computer. Noted products include an IDE interface that plugs into the TRS-80's cartridge slot, memory expansion modules, and NitrOS9. The latter is a full-fledged multi-user Unix-like operating system that runs on the Color Computer.

In addition, DriveWire is available free of charge (as of this writing) as a download from their site. Drivewire information is found in the next section.

Cloud-9's display at the 2014 event included a few decked out Color Computers showcasing their products.

This company has been busy supporting the TRS-80 community by providing innovative products that bring new technology and capabilities to this computer. They have not been stagnant. Cloud-9 reported updates to existing products, as well as new development. Here's a brief summary of some of what has been going on.

The company is finalizing the design of miniFLASH. This will be a product that will plug into the CoCo's cartridge slot (or Multi Pak Interface) and provide four banks of 16K Flash memory to store ROM images. This will eliminate the need to physically swap out ROM cartridges or OSes. The 16K memory banks will be selectable via software or directly by hardware.

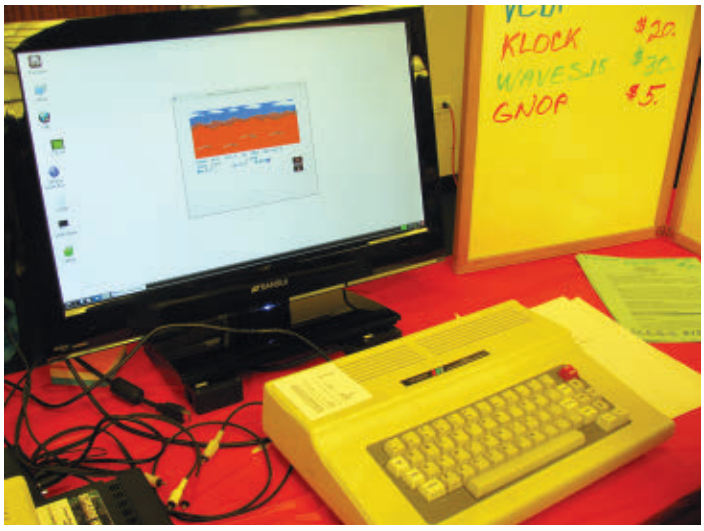
The Cloud-9 exhibit.

Another product provided by Cloud-9 is the DOS adapter. This is a small printed board that plugs into the Color Computer's 24-pin EPROM socket and allows the use of 28-pin EPROMs. The 28-pin EPROMs are easier to find, plus they have an increased capacity over their 24-pin counterparts.

The DOS adapter also incorporates a switching mechanism so that the larger capacity EPROMs can be divided into two banks, meaning that the user can burn the contents of two 24-pin devices into the larger capacity EPROM. Cloud-9 updated this product recently, improving its presentation by including a solder mask and silkscreen on the printed circuit board.

A PS/2 keyboard adapter is another product available from this company. The adapter is a CoCo keyboard hardware emulator that allows the use of any PS/2

Open-case CoCo showcasing Cloud-9's products.



HAWKSoft's Raspberry Pi CoCo 3.

keyboard with the TRS-80. This device also supports keyboard macros and correctly resets the Color Computer when the Ctrl-Alt-Delete sequence is keyed in.

Another innovative product that Cloud-9 has is the SuperSD. This device — a complete embedded system with the ATMEL AVR Xmega 128a1 as its heart — allows using an SD memory card with the TRS-80.

The SD card behaves as though it were a solid-state hard drive, and can be used to store files or ROM images. SuperSD can load these images into the CoCo's memory space emulating a 32K ROM, provided that Tandy's specifications are followed. This will make it easy to load OSes whose image is stored in the SD card in a predetermined folder.

SuperSD is compatible with the FAT file system, using the onboard 64K of fast static RAM to hold the FAT file handle buffers. This means that files can easily be read and written by a DOS/Windows computer, and read or written by the SuperSD. In addition to holding file allocation table information, the memory is also used for the Ethernet buffers and extended memory for the AVR microcontroller.

SuperSD will use the DriveWire protocol to communicate between it and the TRS-80. In addition, this device will also provide a Wiznet expansion slot. Wiznet will be supported by using SPI (Serial Peripheral Interface) controlled by the AVR. Using this platform, Ethernet connectivity will be possible. Lots of firmware that supports various protocols is ready for action, with more on the way.

Another useful feature will be the implementation of AES 128-bit encryption for the firmware files. This allows Cloud-9 to post updates to the firmware on their website. The SuperSD owner only needs to download these files and store them in the SD per instructions. SuperSD will decrypt these files and update its firmware.

HAWKSoft

HAWKSoft — owned and operated by Christopher Hawks — had a display at the CoCoFEST! HAWKSoft is a vendor that provides hardware and software for the Color Computer. Some noted products include an RGB to S-video converter and software that allows NitrOS-9 to read PC CD-ROMs.

By far the most interesting item at the HAWKSoft booth was the Raspberry Pi (RPi) Color Computer. At first glance, it looked just like any other Color Computer 3 with its full travel keyboard and white case, but as Chris explained it was anything but just another Color Computer 3.

First of all, there was no CoCo 3 motherboard or electronics inside the case. Instead, there was a Raspberry Pi that booted into Linux. A CoCo emulator ran within the Linux environment to provide the familiar green welcome screen.

Next, Chris built a small circuit based on the Atmel tinyAVR microcontroller to interface the Raspberry Pi to the TRS-80's keyboard. The small circuit sensed whatever key was pressed on the keyboard and sent the relevant information via the USB interface to the Raspberry Pi.

Chris also added a USB hub and installed it inside the Color Computer case. The various USB ports could be seen peering out of the computer's cartridge slot.

The emulator software took care of correctly interpreting the pressed keys and taking the corresponding action. Chris used the MESS CoCo emulator which works under Linux. MESS is Multiple Emulator Super System, and is capable of emulating various computer systems.

Chris mentioned that the version running on the RPi was a stripped down adaptation that only emulated the Color Computer. This helped reduce the size of the application to something more manageable.

At the time of this writing, Chris was working on putting the software in a publicly available DropBox resource, along with an article that will describe how anyone can build their own RPi Coco. The article will be published in the Glenside Color Computer Club newsletter. The club makes the newsletter available to everyone free of charge. Go to **www.glensideccc.com** to find out how you can receive it.

Richard Crislip's exhibit showcasing DriveWire.

DriveWire

Richard Crislip had a display demonstrating the virtues of DriveWire. This is a software/hardware combo that is used to transfer files between the CoCo and a Windows PC. The software is run on both the host (Windows PC) and the client (the Coco). They communicate via a serial cable (this being the hardware component). Aaron Wolfe is the person behind DriveWire and responsible for a major part of its development.

DriveWire is more than just a way to transfer files between both systems. Tt is also a client/server setup that allows the CoCo to store files on a remote system. This is a great example of how a technology that is considered obsolete is augmented by current technology. By utilizing DriveWire, the user can have storage that is accessible to the CoCo on a remote system. Storage is no longer limited to the physical hardware that can be connected directly to the TRS-80.

In addition to file transfer, DriveWire can perform some TCP/IP networking functions such as Web hosting, Telnet access, and BBS services. This means that given the right software, the Color Computer can connect to the Internet through DriveWire to perform specific tasks (no, a graphical Web browser is not one of them).

The setup that was used to demonstrate DriveWire was also unique. Richard had two monitors to show the CoCo's screen. The first was an old NTSC monochrome monitor. The second was a modern VGA LCD flat panel display. By using a video switch, Richard was able to have both the CoCo and the Windows PC hooked up to this single LCD monitor. Since the TRS-80 does not have a standard VGA output, Richard used a video converter that accepted the CoCo's video signal and converted it to VGA. Again, the fusion of old and new technology was present. To see a video of DriveWire in action, go to **www.youtube.com/watch?v=HU85qTOhWx8**.

The official DriveWire website is **https://sites.google.com/site/drivewire4/**.

Altera DE1 FPGA CoCo 3.

FPGA Color Computer Emulator

Another perfect example of the fusion of old and new

The Glenside Color Computer Club proudly announces the 24th Annual "Last" Chicago CoCoFEST! Highlights of this year's event will include:

Back to Basics theme: This year's theme celebrates the BASIC programming language and its recent 50th anniversary. Various devices — including the Dartmouth College Time-Sharing System (DTSS) emulator — will be on display. All BASIC programmable computers are welcomed.

Auction: This event is a staple of the CoCoFEST! that allows attendees to bid on a wide variety of hardware and software for the TRS-80 and, in some cases, for other vintage computers.

DriveWire: This unique piece of software allows the CoCo and some other vintage computers to use a modern computer as a storage device and communications hub.

Linux: Vintage computer collectors can see how this popular operating system can be leveraged to provide an expansion path and operating environment for a favorite vintage computer.

Projects in Development: These include a CoCo App store, hardware to connect the CoCo to the Internet, Raspberry Pi integration (emulator, DriveWire server), and SD card integration for added storage in a reliable and modern medium.

Vendors: People passionate about preserving our computing past have developed expansion boards and accessories for the CoCo using cutting-edge technology. These include — among others — video adapters for modern displays, memory expansions, and disc storage.

BASIC Programming Contest #1: John G. Kemeny and Thomas E. Kurtz first conceived the BASIC language using a mainframe and the DTSS. Using a DTSS emulator, contestants are challenged to create the best BASIC program possible. The only rule is that the program has to run in the emulator.

BASIC Programming Contest #2: Contestants are challenged to write a BASIC program that will run in the first Color Computer that RadioShack made available to the public. How much functionality can you squeeze into 4K of RAM using only the original Color Basic?

After-hours Rowdiness: The fun does not end when the fest closes in the afternoon. Exhibitors and attendees get together for a fun evening of food, anecdotes, and conversation. Friendships and long-lasting relationships are celebrated and valued as much as the CoCo.

Event Information:
April 25-26, 2015 from 9:00 AM to 5:00 PM
HERON POINT CONVENTION CENTER
645 West North Avenue
Lombard, IL 60148

Entry fee: $5; includes both days/kids under 12 free

Lodging: Special overnight fest rates of $93.24 at the Fairfield Inn & Suites, Lombard. The inn is adjacent to the convention center. See the website for more information at the CoCoFEST! link at **www.glensideccc.com**.

was the Altera DE1 FPGA that was programmed to act as a Color Computer 3 emulator. The Altera DE1 is a "blank" Field Programmable Gate Array (hence, FPGA). The programmer can build a system that will allow the DE1 to mimic a computing device. Once the FPGA is programmed, it behaves as the computer it was programmed to be.

In this case, the programmer put together software for the Altera DE3 that emulates a Color Computer. Its compatibility — although not 100% — is impressive as it runs most software available for the Color Computer 3. The person behind this project is Gary Becker, and he has a Yahoo! Group dedicated to the FPGA CoCo 3 at **http://groups.yahoo.com/group/CoCo3FPGA**.

Here's an introductory overview of the Altera DE1: **www.youtube.com/watch?v=aPXMkTJxD_s**. This next link presents a short demo of the Altera DE1 Color Computer: **www.youtube.com/watch?v=ttf82tPXUko**.

LogiCall

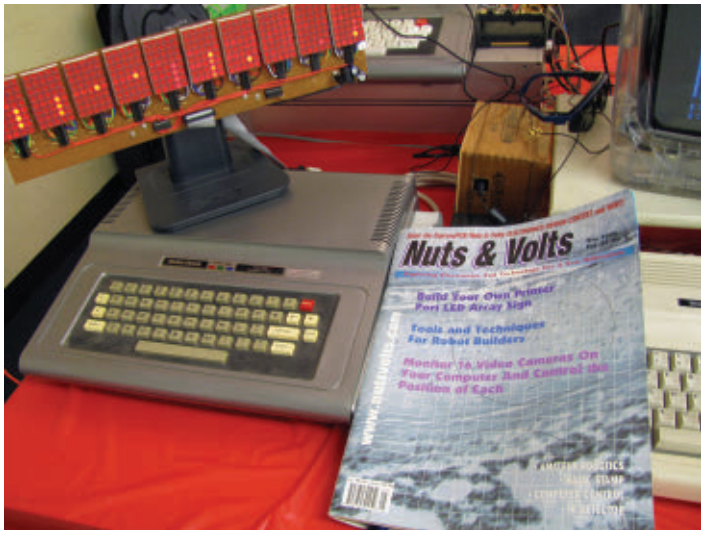
LogiCall 7.0 is a software application that has a history of almost 20 years, and was mainly written by Bob Swoger with crucial and extensive collaboration by John Mark Mobley and Chris Hawks (of HAWKSoft). LogiCall runs on all versions of the CoCo, plus some other computer systems (such as the Sinclair 2068), and provides the user with a basic shell that allows him or her to navigate the file system structure of the attached drives using a menu based system.

Additionally, LogiCall can also accept commands from the user to perform some file operations such as copy, rename, delete, and move, and some administrative operations such as backup and diskette format.

The objective of this software is to make using the Color Computer more visual and intuitive. This is accomplished through the menu structure and its innovative use of one-keystroke commands.

The app's source code is provided so that individuals can customize the software to their unique needs. As an added bonus to registered attendees, LogiCall provided a 16 GB USB Flash drive so that everyone could try it out.

The authors share anecdotes and answer questions.



John Linville's LED array using a CoCo.

History of the Color Computer

Both Boisy Pitre and Bill Loguidice were at the CoCoFEST! to promote their new book, *CoCo: The Colorful History of Tandy's Underdog Computer*, published in December 2013 by CRC Press. This book presents the reader with a detailed history of the CoCo from its conception to its production.

The authors had a round-table discussion that went overtime. Attendees were interested in hearing the stories behind the book and behind the Color Computer. The discussion closed with a question and answer session. Both authors were eager to share experiences and answer the public's questions.

Their book is available through Amazon and can be located easily by searching its title.

More CoCo Stuff

Another interesting display was by John Linville. He had a fully functional LED array display system connected to a Color Computer. This project was built following instructions from an article that appeared in an issue of *Nuts & Volts* dating back to 2000.

A central and strategic fundraising event was the annual CoCoFEST! auction where all sorts of CoCo and some non-CoCo stuff was auctioned off. This event is the highlight of the first day of the event (not counting the festivities that go on after the show). Alas, I had to leave as the auction was getting started, so I can't report a play-by-play of that event.

All in all, everyone had a great time, celebrating friendship and a small underdog computer of the '80s that left a spirit of community and collaboration which is still going strong today. **NV**

BY WARD SILVER N0AX
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Oscillators

Every signal begins with an oscillator — the topic of this column. In ham radio, the oscillator is a key element in generating signals, mixing them together, and extracting the information from them. This month, we'll make an audio oscillator and learn about common types of RF oscillators.

There is an old saying: "Amplifiers are oscillators that *don't* and oscillators are amplifiers that *do*." An amplifier is at the heart of every oscillator, as shown in the block diagram of a basic oscillator in **Figure 1A**. Every single oscillator — even the digital versions, multivibrators like the 555 IC, and the ones in the little metal cans — has this same basic structure: an amplifier, some feedback, and a frequency-determining filter.

Figure 1B shows a pendulum which is an example of a non-electronic oscillator.[1] Given a push, the pendulum will swing back and forth at a constant frequency until friction and air resistance bring it to a halt at the rest position in the center. The frequency-determining element of the pendulum oscillator is its length, L. (Interestingly, the mass of the pendulum doesn't matter!)

The amplifier is whatever delivers the push — such as you. Obviously, the amplifier has lots of gain because you are very strong! By delivering feedback in the form of just the right strength push at just the right time, you can keep the pendulum swinging forever — or at least until dinner.

Switching back to **Figure 1A**, let's imagine an electronic circuit in each block. The idea is for some fraction, *b*, of the amplifier's output signal to be fed back and reinforce its input signal. That input is then amplified with some fed back, so that the output eventually becomes self-sustaining; this is called *oscillation*. Furthermore, to get oscillation only at the design frequency and not just produce random noise, the system must include a filter to provide *selectivity*; meaning that its response is dependent on frequency. The filter can be an LC circuit, a crystal, or a timing circuit — something that is time- or frequency-sensitive.

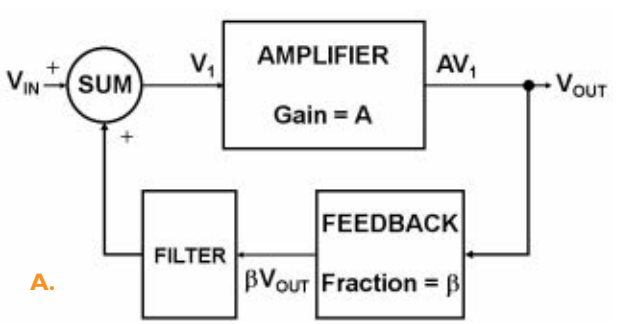
All this creates two requirements for our general-purpose oscillator: First, the amplifier has to have enough gain at the oscillation frequency to overcome losses in the feedback circuit. Second, the filtered signal fed back to the input has to arrive with just the right phase so as to reinforce and not cancel the input signal.

These two conditions make up the *Barkhausen Stability Criterion*:[2]

Loop gain = $|A\beta| = 1$
and
Loop phase shift = $\angle\beta = 0°, 360°, 720° \ldots 360° \times 0, 1, 2$, etc.

(The symbols | | mean "magnitude of," and the symbol $\angle$ means "phase shift of." If you are working with radians instead of degrees, the loop phase shift requirement is stated as $\beta = 2\pi n$, with *n* being an integer value.)

So, just how does the oscillator start up? Noise! Random noise at the frequency for which the phase shift is



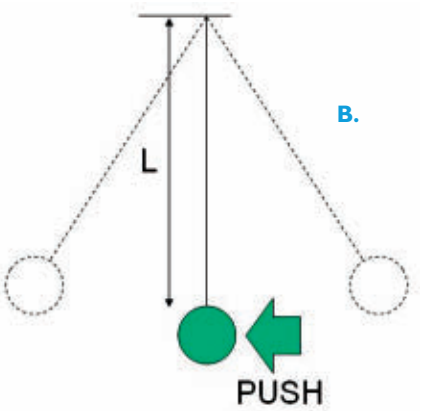


FIGURE 1. The block diagram (**A**) describes an oscillator as three circuits: one providing gain and the other two feeding back a fraction of the output signal into the input through a filter. **B** shows a pendulum which is a mechanical version of the system in **A**.

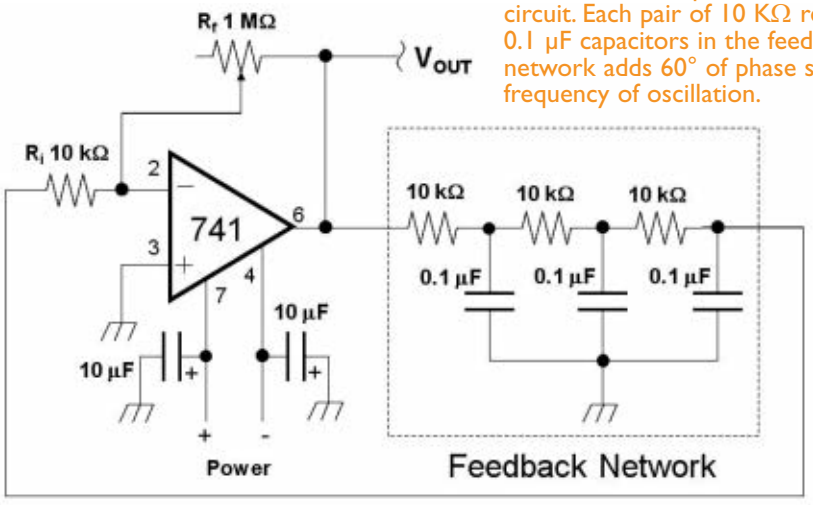


FIGURE 2. The phase-shift oscillator circuit. Each pair of 10 KΩ resistors and 0.1 µF capacitors in the feedback network adds 60° of phase shift at the frequency of oscillation.

just right builds a little bit more around the loop each time. Noise with a phase that isn't just right eventually dies out because it is not reinforced. As a result, the output builds up to a sine wave at the desired frequency.

To keep the oscillator from building up to an infinite output voltage (or trying to), the circuit is usually a little non-linear so that loop gain stabilizes precisely at one when the output reaches the desired voltage.

A Phase-Shift Oscillator

Gain is easy to obtain over a wide range of frequencies. What about phase shift? The required phase shift of 360° can be distributed around the circuit. For example, if the amplifier is an inverting amplifier, it contributes 180° of phase shift. This leaves the remaining 180° to be created in the feedback circuit and/or the filter.

Figure 2 shows a *phase-shift oscillator*. To be sure, there are other circuits with better performance, but this one is the closest to the basic circuit we've just discussed.

Let's start with the feedback and filter circuit formed by the three pairs of 10 KΩ resistors and 0.1 µF capacitors. Each pair forms a low pass RC (resistor–capacitor) filter that shifts the phase of the input signal from 0° to 90° as frequency is increased. At some frequency, the phase shift will be 60°.

The frequency at which each RC section contributes 60° of phase shift is:

$$f = (\tan 60°) / 2\pi RC = 1.73 / 6.28\ RC = 0.28 / RC$$

For our combination of 10 KΩ and 0.1 µF, that frequency is 275 Hz. When three identical sections are cascaded, each contributes its own 60° of phase shift, making up the remaining 180° to form a 275 Hz oscillator.

At the frequency for which 60° of phase shift occurs, the filter also reduces the amplitude of the input signal by half. If three sections are connected back to back, then the total reduction in signal level is 1/2 x 1/2 x 1/2 = 1/8 = 0.125, which is our value of β.

To make $|A\beta|$ at least 1, A must then be at least 8, and that is controlled by the ratio of R_f to R_i. R_f is made variable to allow for adjustment in gain to account for component variations and other effects as we shall see.

Building a Phase-Shift Oscillator

For this circuit, you will need a power supply that can provide both positive and negative DC voltages of 6V to 12V. Since current draw is low, you can use batteries to provide power. An oscilloscope (stand-alone or sound-card based) is required to see the waveforms produced by the oscillator and to make adjustments.

- Start by building the circuit of **Figure 2**. The 10 µF capacitors filter out noise to prevent feedback through the op-amp power supply pins. Set the 1 MΩ potentiometer for the highest resistance between its connections. A 10-turn trimpot will be the easiest to adjust, but a single-turn panel pot will work if you use a knob to make adjustment smoother.
- Connect power; you should see something that looks like a square wave at the output of the op-amp. This shows the op-amp output swinging back and forth between the power supply voltages as the circuit's gain of 1M/10K = 100 is too high for the current in R_f to balance that coming through R_i from the feedback network. As a result, the output jumps between the power supply voltages.
- Reduce the potentiometer resistance to obtain an

Two Spurious Emissions

The value of 2798 used in the January 2015 column to compute the "free-space" length of an antenna in inches was a typo. The correct value is 2952. In addition, the Wireless Institute of Australia (WIA — **www.wia.org.au**) is the world's oldest national amateur radio society, founded in 1910. It was followed by the Radio Society of Great Britain (RSGB –**rsgb.org**) in 1913, and only then by the ARRL in 1914.

undistorted sine wave that peaks a volt or so below the power supply voltages as seen in **Figure 3**. (This may be a touchy adjustment with a single-turn pot.) If you have a dual-channel oscilloscope, observe the input and output voltages of each RC section, and verify that each contributes approximately 60°.

- Measure the period, *T*, of the output waveform (one complete cycle) and calculate the frequency of the oscillator ($f = 1/T$). Measure the resistance of the potentiometer (R_f) after removing it from the circuit. Compute the magnitude of the amplifier's gain ($|A|$ = resistance / 10 KΩ).

You probably observed that the frequency was a lot different than the initial calculation of 275 Hz — my oscillator's frequency was 476 Hz. The voltage drop across each RC filter section was probably greater than half. My sections reduced the output to about 0.27 of the input. The gain of the amplifier will also be found to be greater than eight to compensate for that extra reduction. My potentiometer's resistance was 603 kΩ, for a gain of 60.3 — approximately equal to 1 / (0.27 x 0.27 x 0.27).

These discrepancies result primarily from things we overlooked in the design process. Each RC section does not contribute exactly 60° of phase shift because it is loaded by the next section in the network. That causes an extra voltage drop and phase shift. The op-amp also contributes its own small amount of phase shift, meaning that the total phase shift needed from the feedback circuit will not be exactly 180° at the frequency of oscillation. These two effects result in a higher frequency for the actual circuit at which $|A\beta| = 1$.

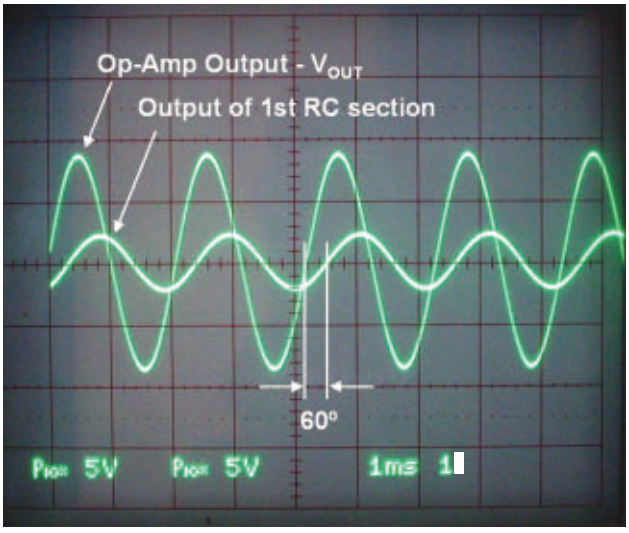


FIGURE 3. The oscilloscope traces show the output signal from the op-amp and the smaller phase-shifted signal at the output of the first RC filter section.

To see the effects of op-amp gain limitations at higher frequencies, change the feedback capacitors from 0.1 µF to 0.001 µF, increasing the 60° phase-shift frequency for each RC section to about 27.5 kHz. At this frequency, a 741 op-amp can't cause its output to change rapidly enough to create a sine wave. (The maximum rate at which the op-amp can change its output voltage is called the *slew rate,* which is measured in V/µsec.) As a result, the output waveform will change to something that looks more like a triangle wave — no matter how you adjust the amplifier gain.

The phase-shift and voltage drop errors caused by the loading effects of each RC section can be eliminated by adding a buffer amplifier between each section. Replace the single op-amp with a quad op-amp such as the LM324. One op-amp section will replace the existing LM741. Add a *voltage follower* between each RC section with an op-amp's output connected directly to its inverting input, and connect the input signal to the non-inverting input. (This circuit is shown as Figure 7 in the Texas Instruments applications note, *Design of op-amp sine wave oscillators.*[3])

Because the voltage follower presents its very high input impedance to the preceding circuit, each RC section can act more like the ideal filter we envisioned during the design process.

The resulting frequency of oscillation and the gain required to achieve oscillation should change to be within 20% of the originally calculated values. (The tolerance of most 0.1 µF and 0.001 µF capacitors is typically 10% to 20%, allowing a lot of variation as well.)

RF Oscillators

The circuits used in RF oscillators are different than those used for lower frequencies. RC phase-shift circuits aren't generally used above a few MHz. The values of R or C become impracticably small, which leaves the oscillator susceptible to stray resistances and capacitances that compromise stability and consistency. In the MHz range, it's much easier to use inductors and capacitors to form the phase-shifting circuits which are referred to as *resonators.*

Most RF oscillators use discrete devices such as a bipolar transistor or FET since most integrated op-amps

Circuit Construction Tutorials

Learning how to build and test circuits at RF is a useful skill but it does take a little practice. Chuck Adams K7QO wrote an excellent and detailed tutorial, *Manhattan Building Techniques*, that can be downloaded from the QRP ME website, whose products are popular with low power ham operators (**www.qrpme.com/docs/K7QO%20Manhattan.pdf**). In addition, you can find all sorts of building tips and instructions by clicking the Radio Technology Topics link at **arrl.org/tech-portal** and in my own *Circuitbuilding for Dummies Do-It-Yourself.*

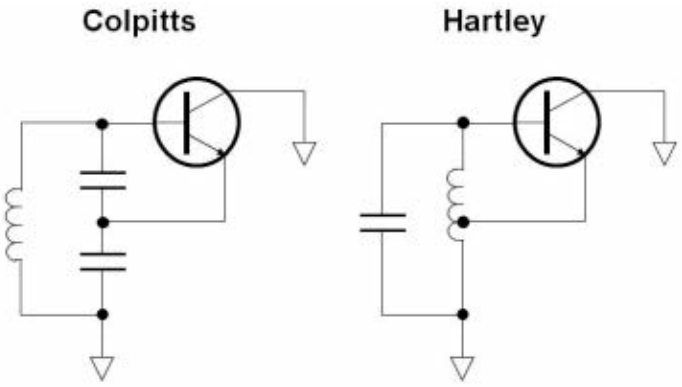


FIGURE 4. The Colpitts and Hartley oscillators work on the same principles but use different connections to the LC filter and feedback circuit, which is called a resonator. (Biasing circuitry is omitted for clarity.)

aren't designed to have the necessary gain at high frequencies. Of more practical concern, a high gain wide bandwidth op-amp is much more expensive than discrete transistors such as the 2N3904 (bipolar NPN) or J310 (N-channel JFET).

Those parts cost mere pennies and have gain at frequencies up to several hundred MHz. As a result, at RF above 1 MHz, the most effective circuits use a transistor amplifier with feedback and the required phase shift provided by a resonator such as a parallel LC circuit.

Meet Hartley and Colpitts

Back in the 1920s, two fellows by the name of Hartley and Colpitts came up with the different circuits in **Figure 4** that became popular in radio designs.

In each, the feedback is provided by routing part of the emitter circuit through a voltage divider created by two reactances (L or C). If the reactive divider is a pair of capacitors, it's a Colpitts oscillator.

If the reactive divider is a pair of inductors or — more frequently — a single inductor with a *tap* part way along the turns, the circuit is a Hartley oscillator. These same circuits are in wide use today nearly 100 years later!

The Hartley and Colpitts oscillator circuits are very similar in behavior, but their differences influence the designer's preferred choice. For example, the Hartley has a wider tuning range and fewer components than the Colpitts.

The Colpitts, however, is less expensive because it avoids the tapped inductor, and has several popular variants with good stability. We'll cover RF oscillators in more detail in the next column.

Prototyping at RF

Most electronics builders and experimenters are very familiar with solderless breadboards. They're very convenient and easy to work with for a variety of circuits, but they aren't very good for analog circuits at frequencies above a couple of MHz.

The strips of contacts add too much capacitance to the circuit in unpredictable ways; the wires and leads of the components start to get long enough to have significant amounts of inductance; and controlling your grounding can be very difficult.

Hams have come up with an excellent substitute for working with RF circuits called "ugly" or "Manhattan-style" construction. In this style of prototyping, a blank piece of copper-clad printed circuit board (PCB) is used as a ground plane. Components needing a ground can be soldered directly to the ground plane.

To create ungrounded junctions ugly style, high value resistors (typically, 1 MΩ or more) are used as standoffs, costing only pennies. In addition, Manhattan-style uses small pads of PCB material as isolated connection points.

The pads are either soldered to the ground plane (requires double-

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2. http://en.wikipedia.org/wiki/Barkhausen_stability_criterion
3. www.ti.com/sc/docs/apps/msp/journal/aug2000/aug_07.pdf

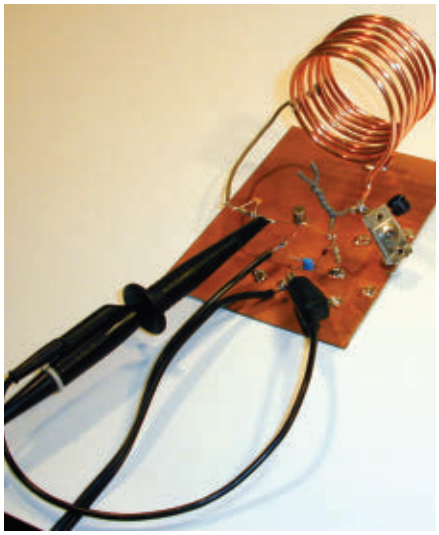

FIGURE 5. A typical RF prototype using "ugly" construction in which ground connections are made directly to the copper PCB ground plane. This is a Hartley oscillator for the amateur 40-meter band around 7 MHz.

sided PCB pads) or hot-glued to the ground plane.

Figure 5 shows a typical "ugly construction" example. This is a Hartley oscillator for the amateur 40-meter band around 7 MHz. In fact, I used a telegraph key to turn this oscillator on and off, making a couple of "QSOs" or contacts with nearby hams using the few milliwatts of power (also known as QRP power) from this mighty peanut whistle!

If you are envisioning doing some RF building yourself, an RF prototyping board is a useful workbench addition. You'll need a large piece of single- or double-sided PCB (at least 8" x 8") and a thick piece of wood as big as or slightly larger than the circuit board.

Drill mounting holes in the corner of the PCB and attach it to the wooden base with wood screws. This gives you a large surface on which to work, plus the base makes it heavy enough to not be dragged about by test leads and cables. I attached rubber feet to the bottom of my wooden base.

Once you've finished (and before each use), scrub the board with a Scotch-Brite™pad to remove fingerprints and oxidation. A swab with some rubbing alcohol will also clean the board of oils or greases. The goal is to have an easy-to-solder surface.

Once you gain a little experience with this type of construction for RF circuits, you'll find it's a quick and effective way to prototype even complex RF circuits before transferring them to an actual PCB or building them into an equipment enclosure. **NV**

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BY LOU FRENZEL W5LEF

THE LATEST IN NETWORKING AND WIRELESS TECHNOLOGIES

New Short-Range Wireless Standards Target IoT Applications

Revised Bluetooth and ZigBee versions feature Internet interconnectivity.

The Internet of Things (IoT) movement is underway and already products are beginning to show up. It is still early in this trend, with billions more devices to be built and connected. However, now it is easier than ever thanks to some updated wireless standards. First, if you are not familiar with IoT, you should see my June 2014 column on this topic. In way of review, IoT is a communications technology that is used to monitor and/or control practically any device by way of a communications link including the Internet. IoT or the Internet of Everything (IoE) — as some call it — includes machine-to-machine (M2M) communications, as well as machine-to-human or human-to-machine. While the IoT movement is just beginning, many in industry predict that from 20 to 100 billion devices could possibly be connected by 2018 or 2020. You may already own one of these devices, such as my video camera that I can monitor via my smartphone from anywhere.

HOW IT WORKS

In most applications, the device to be monitored or controlled has an integrated sensor and wireless transceiver that connects via the cellular system, Wi-Fi, or other wireless link to the Internet. Cellular links connect directly to the Internet, while Wi-Fi or other wireless technologies connect by way of a gateway or router that links to the Web.

The Internet connection contacts a remote server that contains the application software. Then, the monitoring device (like a laptop, tablet, or smartphone) makes an Internet connection to the server to complete the service. Data is then captured and displayed or stored, or some control commands are issued.

All devices are assigned an Internet Protocol (IP) address. Thanks to the latest IPv6 protocol, up to 2,128 addresses are possible. That should be more than enough to handle the largest collection of IoT devices possible.

In almost every case, a wireless link is used for communications. Cellular connections are common for M2M applications like vehicle tracking, pipeline monitoring, or the like. Wi-Fi is popular for home or business applications since home routers and office access points are common.

The fact is that any short-range wireless technology can be used. However, many of the most popular standards do not provide a convenient way to connect to the Internet.

That is now changing. Both of the widely used Bluetooth and ZigBee technologies now offer new versions that are tailored to Internet connectivity.

BLUETOOTH 4.2

Bluetooth is a short-range radio technology that operates in the unlicensed 2.4 GHz industrial-scientific-medical (ISM) band. Bluetooth is a standard of the Bluetooth Special Interest Group (SIG). It has a range up to about 30 feet. The basic output power is 1 mW (0 dBm), but you can use two other power levels for longer ranges: 2.5 mW (4 dBm) and 100 mW (20 dBm). The 4 dBm version is the most popular, but the higher power version can reach out to about 100 meters under line-of-sight conditions.

Bluetooth has a raw data rate of 1 Mb/s, but some of that is overhead that goes to headers and error correction so the net data rate is 723 kb/s. The modulation is Gaussian FSK in a frequency hopping spread spectrum (FHSS) scheme. The carrier hops from one of the 79 channels to another in a random sequence.

The hop rate is 1,600 hops per second for a dwell interval of 625 microseconds. During each hop interval, some data is transmitted. The FHSS method makes the data very secure.

A newer version of Bluetooth is 2.1 – called Enhanced Data Rate (EDR) – and it uses π/4-DQPSK

Go to **www.nutsvolts.com/index.php?/magazine/article/March2015_OpenCommunication** to comment on this article.

modulation that gives a data rate to 2.1 Mb/s. With 8DPSK modulation, the data rate tops out at 3 Mb/s. Version 3.0 – known as Bluetooth High Speed – uses the same transmission protocol, but employs a Wi-Fi 802.11 radio link to get a data rate up to 24 Mb/s.

Version 3.0 was created as a way to let the Bluetooth protocol operate over a Wi-Fi connection if available. Bluetooth radios incorporate an alternate MAC/PHY that is able to dynamically select either the Bluetooth radio or the Wi-Fi radio based on the need for faster transmission, or not.

More recent additions to Bluetooth are versions 4.0/4.1. They feature ultra-low power consumption and encrypted connections. Also called Bluetooth Low Energy (BLE), these radios use very little power and can run for months — even years — on a single coin cell. BLE is also known as Bluetooth Smart.

The BLE versions target anything mobile or portable, including people. The goal is to create wearable wireless devices in watches, running shoes, and medical monitoring devices. Many of the newer Bluetooth chips contain the standard Bluetooth transceiver in addition to a BLE transceiver.

Two newer BLE profiles or applications are the heart rate profile and the temperature profile. Both are designed to enable the wireless monitoring of body functions. They provide a simple way to collect, interpret, and display heart rate and temperature data for training purposes. Other similar applications are on the way.

Aside from the health and fitness areas, the Bluetooth 4.0/4.1 versions also find use in PC peripherals like mice and keyboards, or smart home monitoring and control. BLE is incorporated into smart watches that link to a smartphone, and is also at the heart of beacons — wireless devices that sense when another Bluetooth device is nearby, and transmit location or other information like ads. ICs like the one shown in **Figure 1** make BLE/smart applications easier to develop.

The latest version of Bluetooth is 4.2. It offers greater privacy, security, and reliability of data transfers — even lower power consumption, increased speed, and IP connectivity. It includes BLE features and is backward compatible with previous versions. The main data rate of BLE (1 Mb/s) is boosted to 2.5 Mb/s. However, the big feature of 4.2 is the ability of a Bluetooth device to connect to the Internet.

This new feature uses a protocol called 6LoWPAN with IPv6 to let a Bluetooth device connect through a compatible gateway. This feature — called the Internet Protocol Support Profile (IPSP) — is an application for 4.2 devices. This now makes Bluetooth a prime candidate for IoT applications.

■ **FIGURE 1.** This is Nordic Semiconductors' nRF51822 integrated circuit incorporating a complete Bluetooth smart transceiver, an ARM 32-bit Cortex M0 processor with RAM, and special software that makes BLE applications easier to implement.

ZIGBEE 3.0

ZigBee, like Bluetooth is another short-range wireless standard that has been around a while. It is based on the IEEE's popular 802.15.4 standard. This standard provides the basic PHY and MAC layers of the protocol, while ZigBee adds more layers to implement the applications. The 802.15.4 standard permits operation in the 868 MHz band in Europe, the 902-928 MHz band in the US, and the 2.4 GHz band worldwide.

The most popular version shares the 2.4 GHz band with Bluetooth, Wi-Fi, and a bunch of other wireless technologies.

The standard provides 16 5 MHz bandwidth channels. Modulation is direct sequence spread spectrum (DSSS) with BPSK or O-QPSK. The access mode is carrier sense multiple access with collision avoidance (CSMA-CA). The power level is typically 0 dBm, but up to +20 dBm can be used.

The range is 10 to 100 meters, depending on the power level and the environment. The data rate is 250 kb/s. A key feature of this standard — and ZigBee — is its very low power consumption.

ZigBee is a standard of the ZigBee Alliance. It adds network and application layers to the PHY and MAC layers of 802.15.4. It implements enhancements such as authentication of valid nodes, encryption for security and data routing, and forwarding capability that permits mesh networking.

Mesh networking lets any node talk to any other node (if not directly, then indirectly) by relaying messages

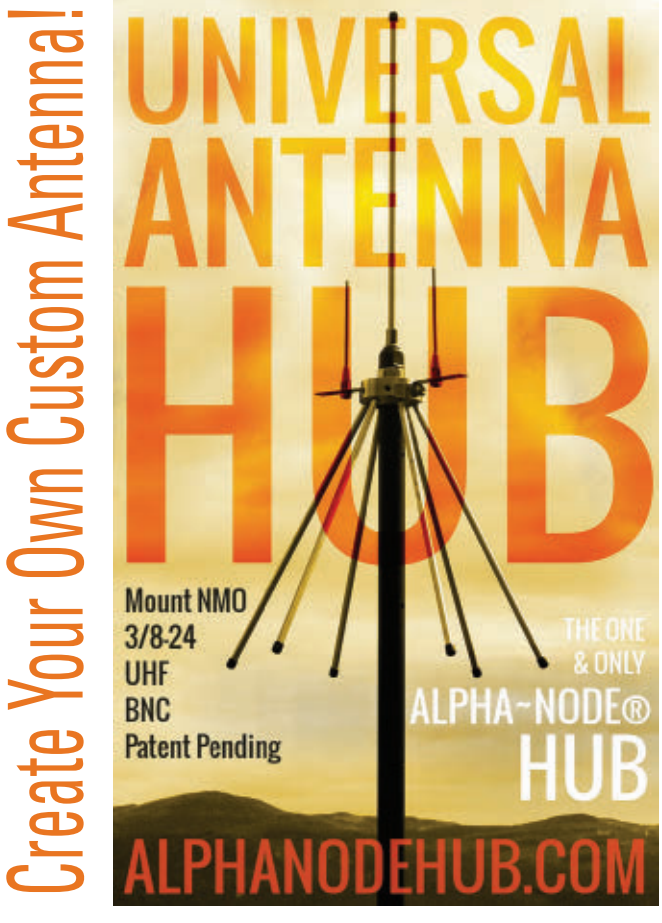
■ **FIGURE 2.** ZigBee 3.0 makes creating home automation and control applications for the Internet of Things faster and easier than ever.

through other adjacent nodes. Mesh networks can be huge and cover a large area. Sensor networks are an example. Plus, ZigBee can connect to the Internet. It uses a variation of the 6LoWPAN protocol.

A key feature of ZigBee is that it offers specific applications for common operations. These are like the Bluetooth profiles. Some of these applications include building automation for control and monitoring of facilities, RF remote controls for home electronics, home energy monitoring, home monitoring and control of devices by smartphone, fitness and health care monitoring, control of LED lighting, and many more.

The latest version of ZigBee is 3.0. What it does is unify many of the available applications into one piece of software. This is especially attractive to IoT developers as it allows communications and interoperability among as many as 130 different smart devices (**Figure 2**). ZigBee 3.0 is compatible with ZigBee PRO, which is a popular version. In addition, 3.0 supports both easy-to-use DIY installations, as well as professionally installed systems.

For more details on these new versions, go directly to the sources at **www.bluetooth.org** and **www.zigbee.org**. **NV**



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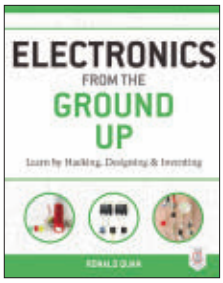

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The TAB Book of Arduino Projects
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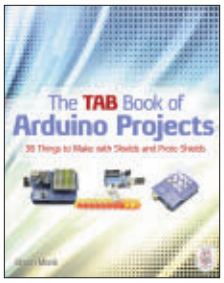

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by Jack Purdum, Dennis Kidder

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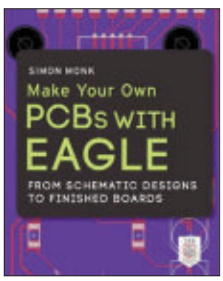
by Eric Kleinert



Featuring detailed illustrations and step-by-step instructions, *Make Your Own PCBs with EAGLE* leads you through the process of designing a schematic and transforming it into a PCB layout. You'll then move on to fabrication via the generation of standard Gerber files for submission to a PCB manufacturing service. This practical guide offers an accessible, logical way to learn EAGLE and start producing PCBs as quickly as possible.

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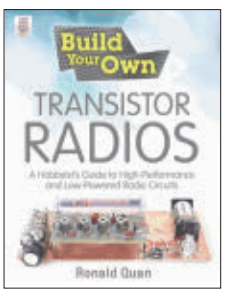

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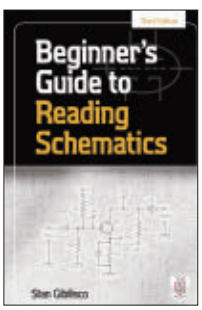
Beginner's Guide to Reading Schematics, 3E
by Stan Gibilisco



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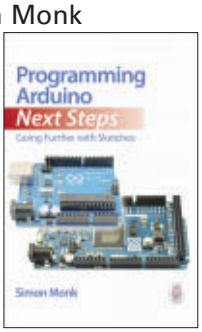
Programming Arduino Next Steps: Going Further with Sketches
by Simon Monk



In this practical guide, electronics guru Simon Monk takes you under the hood of Arduino and reveals professional programming secrets. Also shows you how to use interrupts, manage memory, program for the Internet, maximize serial communications, perform digital signal processing, and much more. All of the 75+ example sketches featured in the book are available for download. **$20.00**

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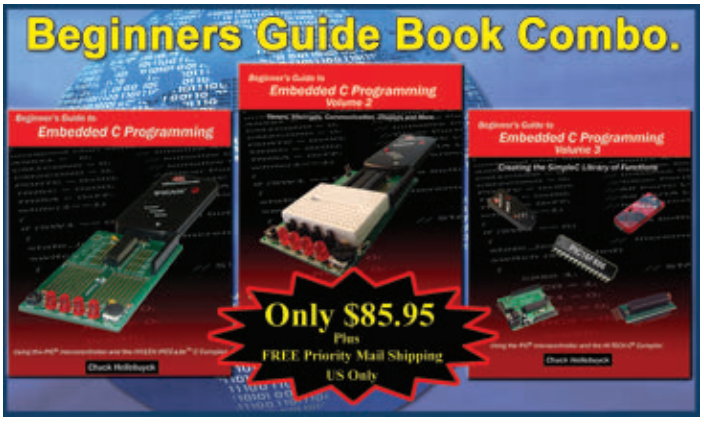

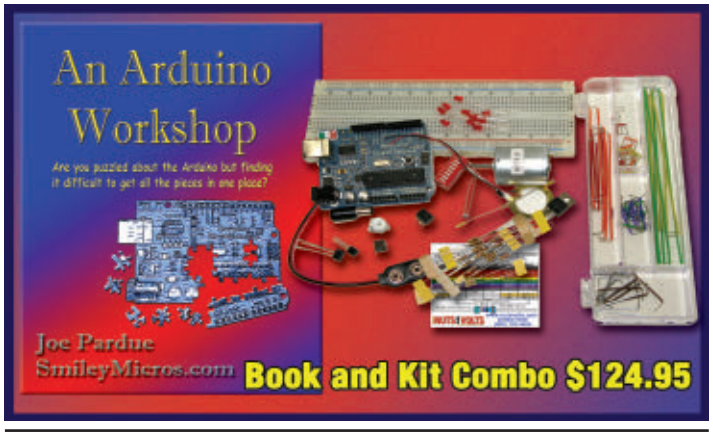

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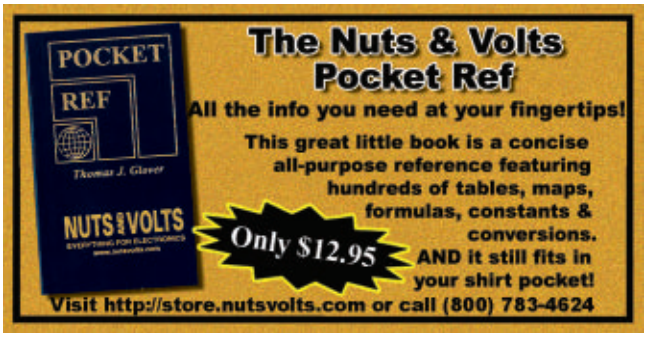

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PROJECTS

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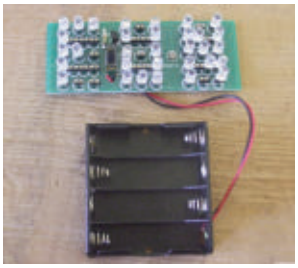

The no nonsense/no microprocessor annunciator is a great little circuit that helps you get your message out without spending too much money. Put two circuits together and you'll have a six letter annunciator!
This kit is also a fun project to refine your soldering skills with its 102 socket pin connection points. WOW, that's a lot of soldering!

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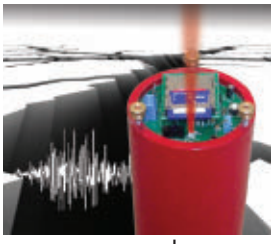
Seismograph Kit



Now you can record your own shaking, rattling, and rolling.
The Poor Man's Seismograph is a great project/device to record any movement in an area where you normally shouldn't have any. The kit includes everything needed to build the seismograph. All you need is your PC, SD card, and to download the free software to view the seismic event graph.

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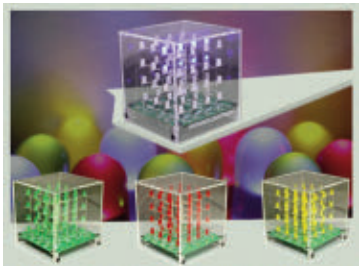
3D LED Cube Kit



This kit shows you how to build a really cool 3D cube with a 4 x 4 x 4 monochromatic LED matrix which has a total of 64 LEDs. The preprogrammed microcontroller that includes 29 patterns that will automatically play with a runtime of approximately 6-1/2 minutes.
Colors available: Green, Red, Yellow & Blue

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Solar Charge Controller Kit 2.0

If you charge batteries using solar panels, then you can't afford not to have them protected from over-charging. This 12 volt/12 amp charge controller is great protection for the money. It is simple to build, ideal for the novice, and no special tools are needed other than a soldering iron and a 9/64" drill!

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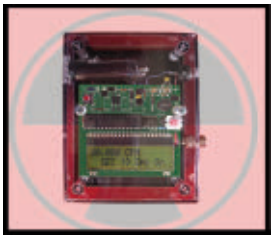

This kit is a great project for high school and university students The unit detects and displays levels of radiation, and can detect and display dosage levels as low as one micro-roentgen/hr.
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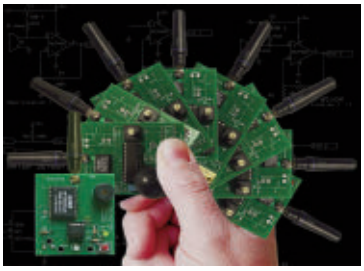
Super Detector Circuit Set



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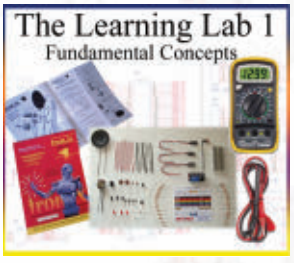

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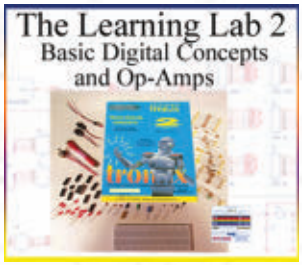

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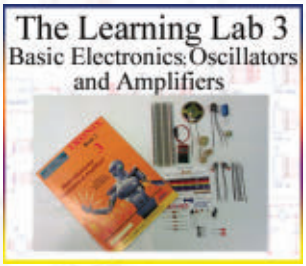

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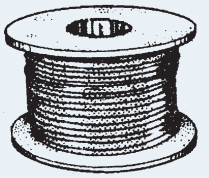

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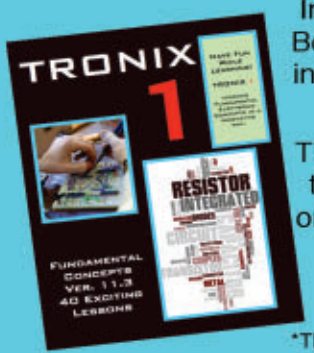

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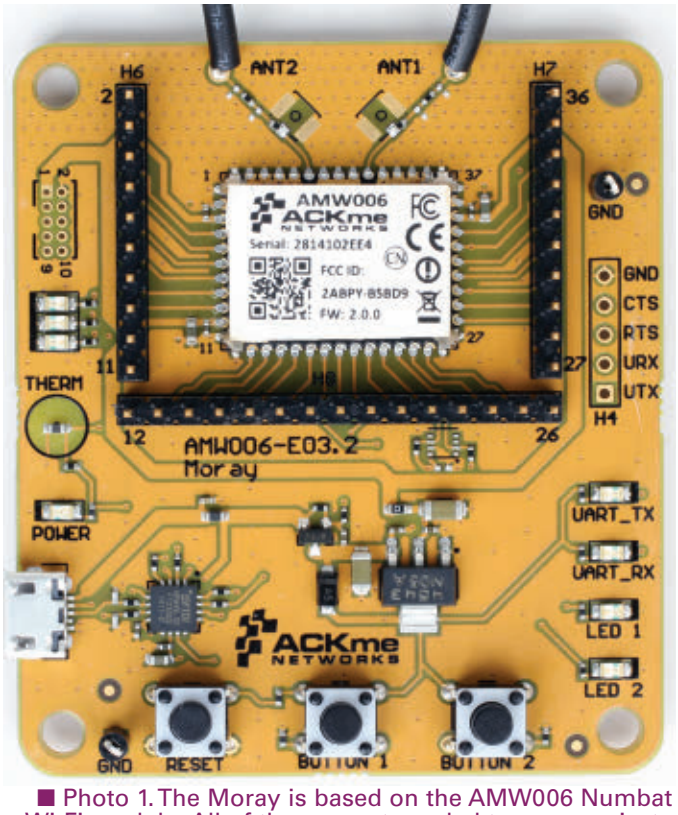
■ BY FRED EADY

A Blueprint for Embedded Wi-Fi

Let's face it. You are a *Nuts & Volts* reader because you compute. You compute with a PC that utilizes large microprocessors, spinning disk drives, and megabytes of memory. You also compute with microcontrollers and relatively small amounts of memory. Each compute platform has a mission. Normally, the larger PC platform is used to craft smaller microcontroller-based solutions. Once the microcontroller application is spawned, the larger mothership compute platform is jettisoned. The microcontroller hardware then assumes all responsibilities of the resultant application. We have become accustomed to having the target microcontroller perform the bulk of the application activity. However, the paradigm is changing. Smart peripherals are assuming communications, control, and sensing functions that were normally relegated to the microcontroller in charge of the application. In these cases, the microcontroller becomes a simple mouthpiece that shouts out commands to the attached smart peripheral. The smart peripheral performs the work and reports its results to the requesting microcontroller. As a result, the microcontroller does not have to be endowed with a huge amount of compute resources. In this installment of Design Cycle, we will create a bit of mouthpiece microcontroller hardware supported by C application code generated by the CCS C compiler.



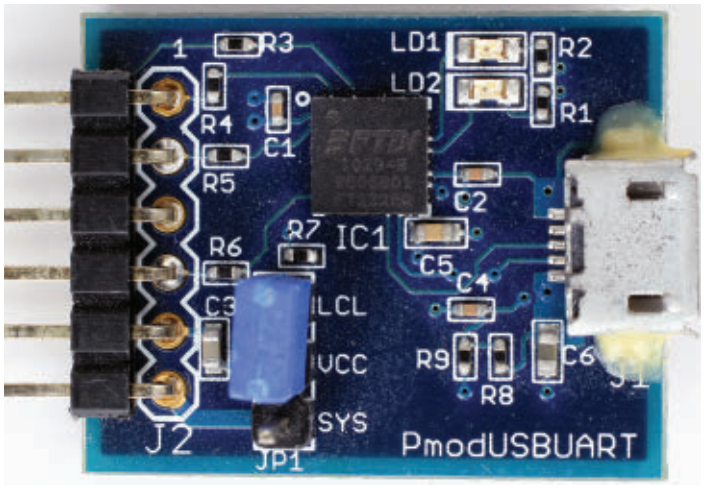
■ Photo 1. The Moray is based on the AMW006 Numbat Wi-Fi module. All of the support needed to communicate with the Numbat can be found on the Moray printed circuit board.

Hardware — From the Beginning

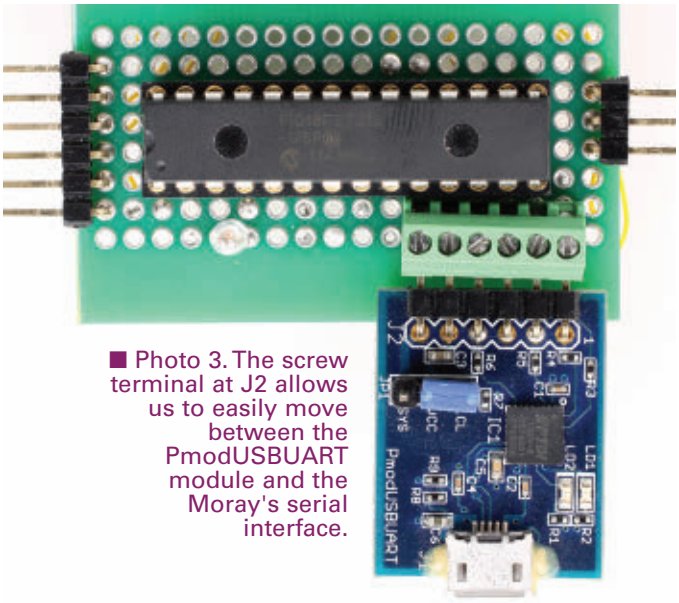
We have full access to the slave device which, in this case, will be the Moray Wi-Fi module you were introduced to last month. So, we know what the Moray wants to hear and how the Moray will respond. As you can see in **Photo 1**, the Moray is a self-contained embedded Wi-Fi platform. Power and serial connectivity is provided via the Moray's integrated FTDI USB interface.

Our host microcontroller does not have native USB host support in its arsenal, so we will have to get our serial signal into the Moray the old fashioned way. To do this, we will have to perform some surgery. However, before we start cutting traces, we will make sure that we have all our ducks in a row on the microcontroller side of the creek. We can line up our duckies by emulating the Moray signals with a terminal emulator.

The microcontroller mouthpiece hardware design is as



■ Photo 2. Those of you that have previously visited the Design Cycle space will recognize this little device as a workhorse I use very often to add instant USB connectivity to embedded projects.



■ Photo 3. The screw terminal at J2 allows us to easily move between the PmodUSBUART module and the Moray's serial interface.

simple as it gets. As you can see in **Schematic 1**, our mouthpiece hardware design consists of a PIC, two resistors, three capacitors, a couple of connectors, and an LED for fun. To facilitate easy communications to a terminal emulator that will be running on my Lenovo laptop, J2 is wired to directly interface a Digilent PmodUSBUART module. The PmodUSBUART is shown in **Photo 2**.

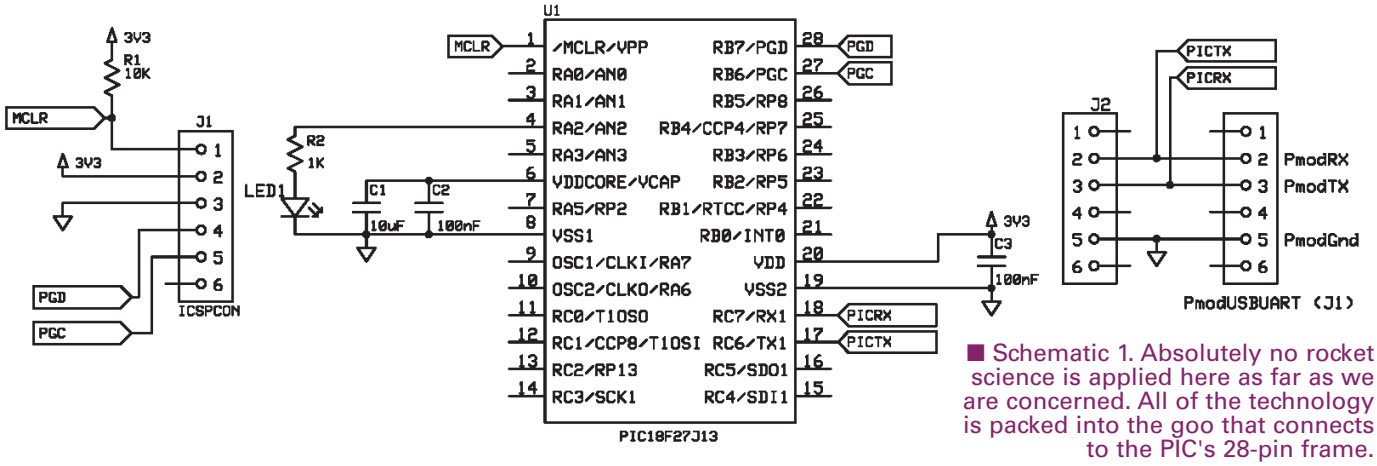
The heart and soul of our mouthpiece design — a 28-pin PIC18F27J13 — is shown with the PmodUSBUART mounted in the J2 screw terminal in **Photo 3**. Once we've verified that our firmware is working as designed, we can replace the PmodUSBUART module with a connection to the Moray's serial interface.

Note the crossed Rx and Tx signals between the PmodUSBUART module and the PIC's serial interface. We must also connect to the Moray's serial interface in this manner. A serial port is always good to have in any case as it can act as a debug device.

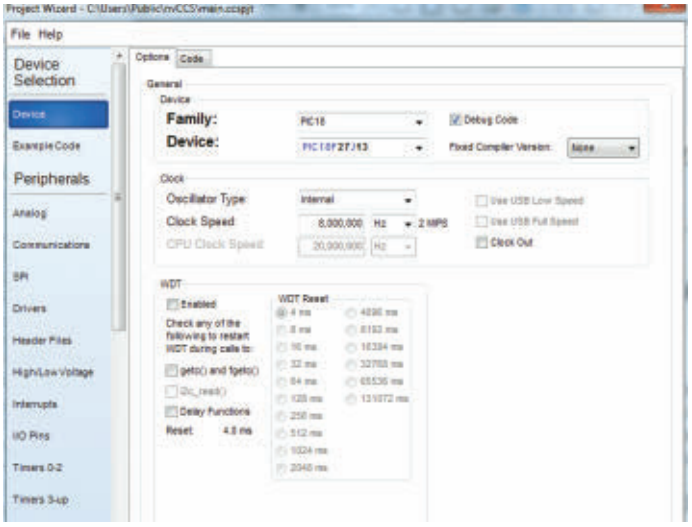
In this design, we've added what I call an "activity" LED that can be used for general-purpose debugging or as an "I'm alive!" indicator. The PICkit3 has proven to be a reliable and popular programmer/debugger device. J1 is wired to allow a PICkit3 to be directly plugged into the design for programming and debugging.

The PIC18F27J13 is a very capable microcontroller. However, the objective here is to not have to utilize any of the PIC's native resources. The Moray can sense analog voltages for us. It can also perform general-purpose I/O functions via commands issued by the PIC. The Moray's PWM engine allows us to utilize it in applications such as light dimming or digital-to-analog voltage generation. In essence, we are holding the PIC's resources in reserve. Any task that the Moray cannot perform can be performed by compute and I/O resources native to the PIC.

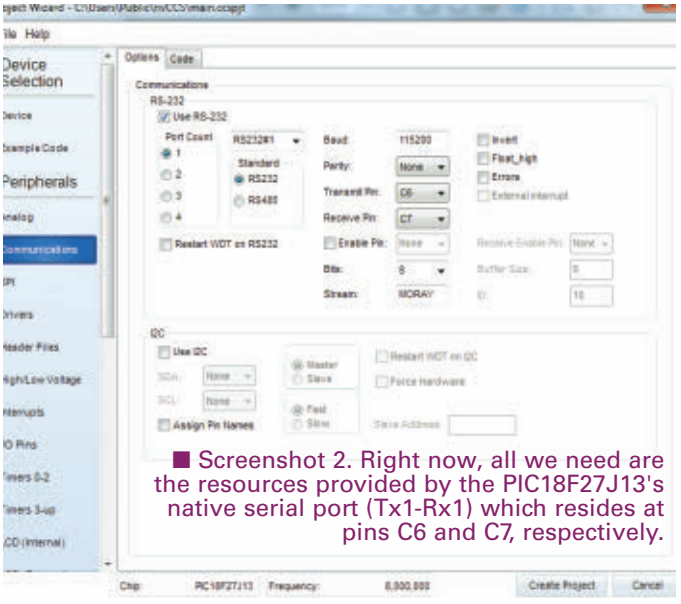
For instance, the Moray does not support SPI master mode. So, we would call upon the PIC18F27J13 to step



■ Schematic 1. Absolutely no rocket science is applied here as far as we are concerned. All of the technology is packed into the goo that connects to the PIC's 28-pin frame.



■ Screenshot 1. This is a screen capture of the CCS C Project Wizard. This window is where the clocking, watch dog timer, and debugger information is entered for our selected device. Our entries automatically generate the necessary configuration code, which we will plug into our application's C source code.



■ Screenshot 2. Right now, all we need are the resources provided by the PIC18F27J13's native serial port (Tx1-Rx1) which resides at pins C6 and C7, respectively.

up and perform any SPI master tasks the application would require. The Moray's strength lies in its ability to communicate via Wi-Fi radio. The Moray's GPIO capabilities are gravy on the biscuit.

Firmware — From the Beginning

To be successful, we must think out our firmware design in the same way we have to plan and prepare our hardware design. The CCS C compiler is super capable and super easy to use. Thus, our firmware thought process shouldn't produce a lot of ear smoke.

Let's take it from scratch. We know our target microcontroller is a PIC18F27J13. According to **Schematic 1**, there is no external clocking device (such as a crystal) incorporated into the design. So, we can bet on using the PIC's internal clocking mechanism. Since there are no predetermined crystal frequencies specified in the schematic, we can call the shots ourselves.

The PIC18F27J13 is equipped with an internal oscillator that ranges from 31 kHz to 8 MHz. We can use the PIC18F27J13's 4x PLL to kick the MCU clock frequency up to a maximum of 32 MHz. Our alternative PLL-boosted frequency is derived from the 4 MHz internal clock setting and is presented to the MCU as 16 MHz. We don't need lightning in a bottle. So, we'll drive our PIC18F27J13 at 8 MHz.

We can construct the proper C source by hand to define our PIC selection and the clock speed of 8 MHz. However, that is not necessary. The C compiler comes standard with a Project Wizard that does a lot of this manual coding work for us. Take a look at **Screenshot 1**. In this screen capture, we enter the PIC type, the desired clock frequency, and clock source. We also specify if we want to debug this project's code. A watch dog timer (WDT) check box lets us decided if we want to enable the WDT or let is sleep quietly in the dog house.

If we move methodically and logically in our Project Wizard path, the next configuration item will be Communications. Recall that the Moray is perfectly capable of performing any analog functions that we know we may need at this moment. We configure the PIC's communications resources within **Screenshot 2**, which is a screen capture of the Project Wizard's Communications configuration window. All we need is simple RS-232 capability in a three-wire configuration (RX, TX, GND).

As you can see in the screen capture, we have selected the PIC18F27J13's native RS-232 port at pins C6 and C7. The PIC18F27J13's serial port configuration is set for eight data bits, no parity, and one stop bit. The Moray defaults to 115200 baud and we have set our PIC serial port up likewise. In the event that we need to use the PIC18F27J13's other serial port, we can provide another unique Stream name other than MORAY.

Streams allow us to direct serial I/O to a specific serial port by name. In this case, we are only using the default

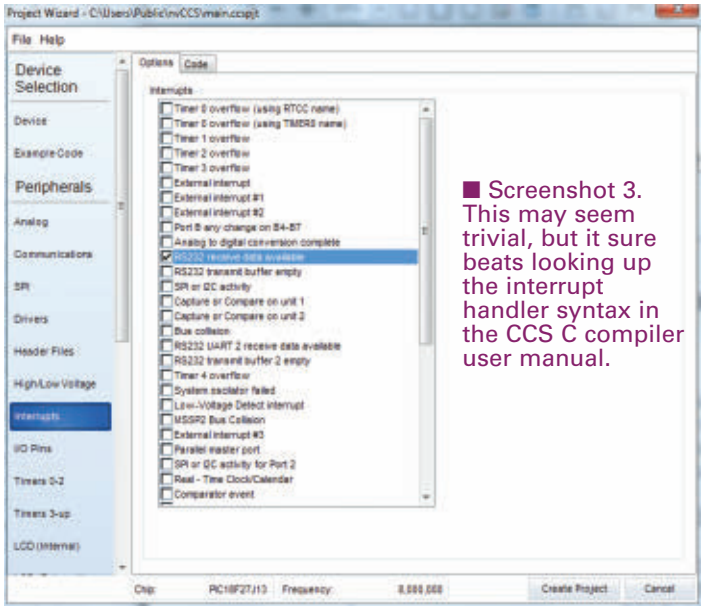
RESOURCES

Lemos International
Wi-Fi Development Board
www.lemosint.com

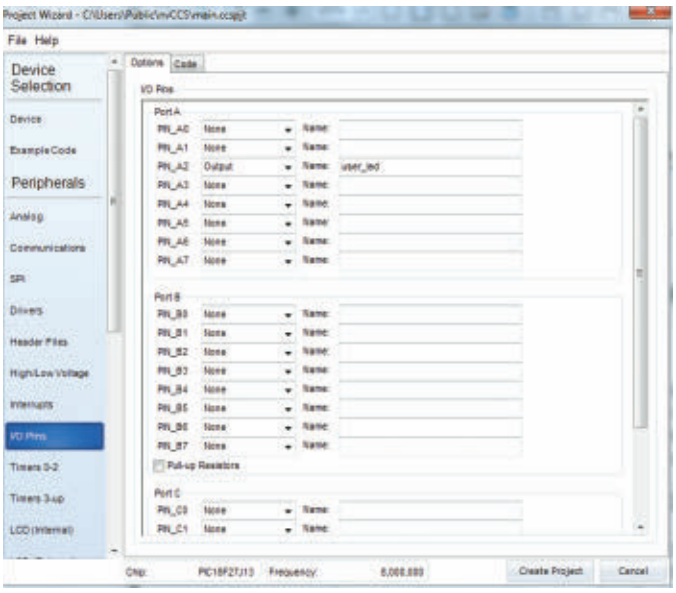
CCS
CCS C Compiler
www.ccsinfo.com

Microchip
PICkit3
PIC18F27J13
www.microchip.com

■ Screenshot 4. According to Schematic 1, we have an LED hanging on I/O pin A2. So, here we name the LED and specify the I/O pin it is attached to as an output pin.



■ Screenshot 3. This may seem trivial, but it sure beats looking up the interrupt handler syntax in the CCS C compiler user manual.



serial port. So, we can opt to use MORAY in a stream statement if we wish. Otherwise, we can successfully execute serial operations using the PIC18F27J13's EUSART without specifying a Stream name.

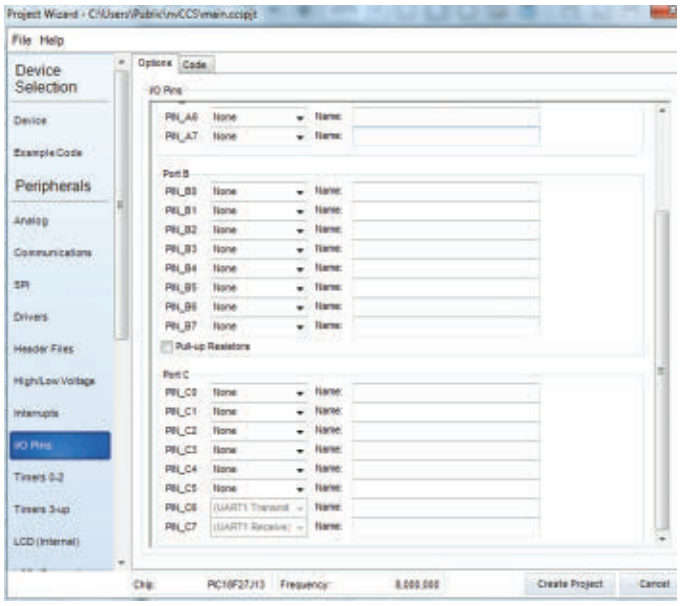
The selections you see in **Screenshot 2** will generate the necessary code to initialize the PIC18F27J13's EUSART as we have specified. The baud rate calculation will use the 8 MHz clock speed we defined in **Screenshot 1**. One of the biggest strengths of the CCS compiler is its built-in delay functions. By simply declaring the delay time, the compiler can produce the code necessary to delay in CPU cycles, milliseconds, or microseconds. The delay functions are also based on the CPU clock speed.

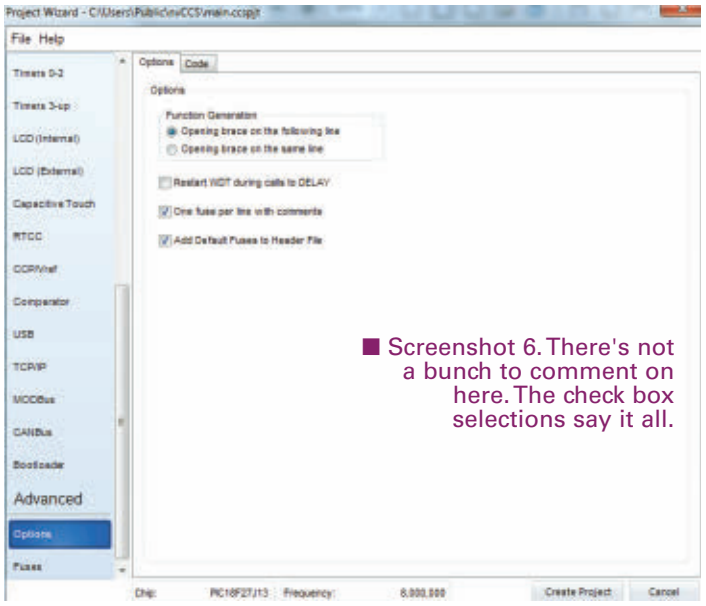
Now that we have laid the groundwork for our RS-232 communications portal, we'll need to build a framework to deal with the data it will handle. The best way to corral incoming RS-232 data is to use an interrupt at the corral gate. The CCS compiler's Project Wizard will generate the interrupt handler skeleton, but it will not generate our interrupt handler code. We'll worry about the interrupt handler code later. Right now, let's just get the posts in the ground.

Our corral post hole digger can be found in the Interrupts shed of the Project Wizard. All we have to do is check the correct box in **Screenshot 3**. How do we know which check box to select? We are calling the shots, remember? Let's choose to only interrupt on received characters. There is no real need to interrupt on transmitted characters. We know what we're sending. It's the responses from the Moray that are important to us. So, we must build a firmware mechanism to capture and store the Moray's responses until we're ready to process them. That's a to-do we'll take care of a bit later.

If you add hardware, odds are you'll also be adding code. If we're going to use that "activity" LED, we have to announce its presence to the firmware. Normally, we would simply code an alias for the LED and set up the I/O pin that services the LED as an output. Nothing changes with our C compiler except we instruct the Project Wizard

■ Screenshot 5. The CCS C Compiler Project Wizard is an interlocked set of selection windows. If we decide to do something that affects the decisions available elsewhere in the process, the Project Wizard takes care of the details.



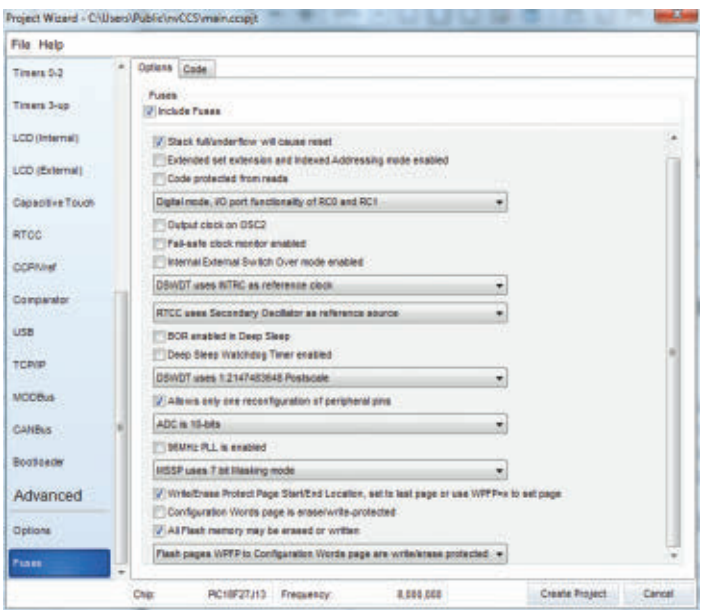


■ Screenshot 6. There's not a bunch to comment on here. The check box selections say it all.

to generate the alias and pin direction code for us. You can see how tough an assignment this is in **Screenshot 4**. All we have to do is name pin A2 (provide an alias) and designate it as an output pin. That's all there is to it.

Now, you're thinking we have those RS-232 pins defined. What if I accidentally "reassign" their functions? Well, the CCS compiler software folks are way ahead of you. Check out **Screenshot 5**. The I/O pins that are natively assigned to the EUSART have been reserved for that purpose.

Pins C6 and C7 are multiplexed with other functions. Our specifying their functionality in **Screenshot 2** carries over to the I/O pin definitions that reside in **Screenshot 5**.



■ Screenshot 7. I really could have left these check boxes alone, but NOOOOO.

Most of the time, the less extra fluffy stuff you see in your source code, the better. However, I'm the kind of guy who likes to have total visual access. So, I chose to display all of the PIC18F27J13's fuse settings. I'm also a fan of placing the opening braces of functions and such on the following line. All of that is evident in **Screenshot 6**. Now that you know I'm a configuration fuse freak, I verify this extremism by electing to populate the check boxes in the Fuses area of the Project Wizard. My personal fuse preferences are reflected in **Screenshot 7**.

What Have We Done?

Well, nothing much yet. However, with the click of the Create Project button, an include file and a main project file are created. Each of the newly generated files contains code and definitions based on selections we made in the Project Wizard windows. Here are the contents of the *main.h* file:

```
#include <18F27J13.h>
#device ADC=16

#FUSES STVREN
    //Stack full/underflow will cause reset
#FUSES NOXINST
    //Legacy mode
#FUSES NOPROTECT
    //Code not protected from reading
#FUSES SOSC_DIG
    //Digital mode, I/O port functionality of
    //RC0 and RC1
#FUSES NOCLOCKOUT
    //I/O function on OSC2
#FUSES NOFCMEN
    //Fail-safe clock monitor disabled
#FUSES NOIESO
    //Internal External Switch Over mode disabled
#FUSES DSWDTOSC_INT
    //DSWDT uses INTRC as reference clock
```

```
#FUSES RTCOSC_T1
    //RTCC uses Secondary Oscillator as reference
    //source
#FUSES NODSBOR
    //BOR disabled in Deep Sleep
#FUSES NODSWDT
    //Deep Sleep Watchdog Timer disabled
#FUSES DSWDT2147483648
    //DSWDT uses 1:2147483648 Postscale
#FUSES IOL1WAY
    //Allows only one reconfiguration of
    //peripheral pins
#FUSES ADC10
    //ADC is 10-bits
#FUSES MSSPMSK7
    //MSSP uses 7 bit Masking mode
#FUSES WPFP
    //Write/Erase Protect Page Start/End Location
#FUSES NOWPCFG
    //Configuration Words page is not
    //erase/write-protected
#FUSES WPDIS
    //All Flash memory may be erased or written
#FUSES WPEND
    //Flash pages WPFP to Configuration Words
    //page protected

#device ICD=TRUE
#use delay(internal=8000000)
#use FIXED_IO( A_outputs=PIN_A2 )
#define user_led    PIN_A2

#use rs232(baud=115200,parity=N,xmit=PIN_C6,rcv=
PIN_C7,bits=8,stream=MORAY)
```

Following the inclusion of the PIC hardware definition file *18F27J13.h*, all of the fuse settings we selected and the default fuse settings are exposed to the compiler. Recall that we opted to have a means of debugging the code, which resulted in the *#device ICD=TRUE* directive. You can also see the obvious declarations alluding to the delay functions' time base, the LED I/O pin, and the LED alias, respectively. The final line of code in the *main.h* file sets up the PIC18F27J13's EUSART with a CCS compiler *#use rs232* directive. All of the directive code that follows the fuse declarations replaces code we would normally write to set up the CPU clock and LED I/O pin.

To-Dos No More

I've filled in the blanks. The receive interrupt skeleton generated by the Project Wizard has been populated with a nifty serial receive interrupt handler that feeds a 256-byte circular buffer. I've also written a function called *recvchar* that pulls characters out of the circular buffer in the order in which they arrive. There's also a routine to check for characters in the circular buffer that are yet to be retrieved. The main application blinks the activity LED every 100 mS and looks for incoming characters. All incoming characters are echoed back to the sender.

So, all you have to do is hook up the PIC18F27J13/PmodUSBUART combination to a PC USB port and kick off your favorite terminal emulator. I've provided the C source code for download at the article link, so all you have to do is compile the code and load it into your version of the PIC18F27J13-based hardware described in this text.

Connecting to the Moray

You can download the Moray schematic from the Ackme website (**https://ack.me**). You will see that all you really have to do is bypass the Moray's USB portal. You can power the Moray with an external +5 volt power supply if you decide to tap in before the Moray's onboard voltage regulator. You will only need a +3.3 volt supply if you bypass the regulator all together. The Moray's UART Rx and Tx signals are available at the Moray's male I/O header.

The Moray technical documentation describes in detail the commands and responses that pass over the serial connection. You can emulate the sequences by sending them to the PIC18F27J13 using the terminal emulator. The CCS C compiler IDE debugger allows you to peek into the PIC18F27J13's EUSART receive ring buffer and examine the Moray's responses.

Thanks to the CCS compiler and a PIC18F27J13, you can now add embedded Wi-Fi to your Design Cycle. **NV**

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>>> QUESTIONS

X10 Cable Build

I have an early X10 Home Control Timer (Model CP-290) to which I have lost the programming cable. Does anyone know where I can get the pinout so I could fashion my own replacement cable?

#3151 **Leigh Guzman**
Oxnard, CA

Lightning Protector

In a recent thunderstorm, a nearby lightning strike took out some of the electronics at my neighbor's house. Is there anything a DIY'er like me can build to protect my delicate electronics — other than unplugging everything? Something with MOVs maybe?

#3152 **Matthew Hodges**
Wichita, KS

PCB Chem Disposal

I'm interested in photo etching copper-clad PCBs. Most guides don't say what to do with the chemicals when I'm done. Do I just pour them down the drain or will it hurt the environment (or my pipes?).

#3153 **Gerardo Rios**
Phoenix, AZ

Arduino Remote

My Sony BluRay/DVD player came with a very complicated remote control. I don't need half the buttons! Is it possible to make a simplified replacement remote using an Arduino and simple buttons with an IR-LED?

#3154 **Terence Rodriquez**
Raleigh, NC

>>> ANSWERS

[#2152 - February 2015] Battery Dilemmanator

About three years ago, I put together a 1.5 volt battery eliminator using a wall wart feeding into an LM4120 regulator to power the clocks I have around the house. The clock that I started with is a Howard Miller mantle clock that a company awarded to me for busting my ass for 25 years.

After installing the eliminator, I set the clock to the time of my crack atomic wristwatch and let'er go. The clock ran for almost three years with phenomenal accuracy, matching my watch within a few seconds but finally died — probably from exhaustion — having gotten no rest between battery exchanges.

Well, I thought, what are you waiting for. Get with it with the other cheap clocks cluttering up our house; so, I did. To my amazement, none of the clocks running on the eliminator could keep time anywhere near what could be termed accurate — no matter how much I adjusted the voltage (usually, the clocks ran fast).

So, what gives? Why does a battery work and my eliminator won't?

#1 I recommend looking at the LM4120 output with a DC coupled oscilloscope and checking for noise or voltage drift, either short-term or long-term. I think you will see the problem.

John Keller
via email

#2 Without more information, it's difficult to give a definite answer, but here are three possible causes to check:

1. Is the output voltage correct? Check with a DVM; anything from 1.35V to 1.6V should be okay for LCD or quartz clocks.

2. The power supply has excessive AC in the output, e.g., a bad capacitor. Though you could check this with an audio amplifier or oscilloscope, it's easier to just put a 500 microfarad or larger electrolytic cap across the output and see if that fixes the issue.

3. AC or RF leakage from the power supply — either from the mains or from a nearby radio transmitter — is making its way into the clock. The clock circuitry is very low power, so any AC could flip some flip-flops a few extra times per second. To check this, you could make a Faraday cage *(e.g., window screening)* around the clock and connect it to one side of the supply. This is to satisfy your intellectual curiosity, though it's probably not a convenient way to run a clock.

B. Bresnik
via email

#3 First off, I suggest the following:

1. Measure the OPEN-CIRCUIT output of your eliminator before connecting it to the clock you want to run.

2. Connect the eliminator to the clock, then measure the voltage output again.

If the difference between the "no-load" voltage and "load" voltage is more than 0.5 VDC, it's entirely possible your wart isn't delivering enough *current* to properly operate the regulator. In this case, try a similar-voltage wart with higher current output (say, 1.5-2X of your current wart). This may solve the problem as wall wart outputs tend to droop severely once you approach their maximum current capability, resulting in *severe* output instability (i.e., the regulator won't "regulate" well), increased ripple, noise on the DC output, and severely shortening the life of the wart (i.e., over-

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Always use common sense and good judgment!

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or via the online form at **www.nutsvolts.com/tech-forum**

heating and such).

If the "no-load/load" voltage difference is negligible (<0.1 VDC), try adding a filter capacitor (start with a 470 µF electrolytic — watch the voltage rating of the cap!) paralleled with a 0.01 µF mica or polyester to filter out high-frequency *hash* that may be on the DC output feeding the clock. This may give you the stability you're looking for as most — if not all — warts are *half-wave unregulated* types with very minimal filtering to begin with. Adding more filtering (larger electrolytic) and *bypass* (small value) caps to the DC output greatly improves their overall stability and *cleanliness* of the DC output voltage.

Finally *(as you already know)*, having a regulator between the wart and your device guarantees a rock solid DC source, *as long as you don't pull too much current from the wart.*

Ken Simmons
Auburn, WA

[#2153 - February 2015]
Diode Decision

Can you PLEASE indicate which germanium diode would best fit this SW radio? Either a 1N34A or 1N60?

#1 Both diodes — 1N34 and 1N60 — are germanium diodes, and both are of similar physical size. The important thing is that this diode family has the smallest forward voltage characteristic, which is important for rectification of small voltages. They both will operate at radio frequencies. The forward current rating and the reverse voltage characteristics are unimportant in this application.

Bottom line: Either one will work in this application. My personal choice would be the 1N60 because the documentation available for this device is superior, with V-I curves to show the typical forward voltage characteristic.

Peter A. Goodwin
Rockport, MA

#2 Either should work well. Both have a conduction knee starting around 0.15 or 0.20 volts. The IN60 — being slightly newer — probably has more tightly-controlled specs. Here's a source for diodes and their specifications: **http://store.americanmicrosemiconductor.com/1n60.html** and **http://store.americanmicrosemiconductor.com/1n34a.html**. BTW, for better Q of the tuner, connect the diode to a tap on the coil.

B. Bresnik
via email

Send all questions and answers by email to **forum@nutsvolts.com**
or via the online form at **www.nutsvolts.com/tech-forum**

#3 You can use either type and expect the same results. Both diodes are germanium and both have a forward voltage drop (often called "turn-on" voltage — where a diode begins conducting) of about 0.3V. A diode with even lower forward voltage is the 1N5817 — a Schottky diode — which has a forward voltage of about 0.16 volts. The forward voltage determines how weak a signal can be heard.

The author at the following URL presents a comprehensive table of 1N34 and 1N60 subtypes and a few Schottky diodes used as detectors in crystal radios. If you view it, look in the column labeled Measured Vr: **http://wiki.waggy.org/dokuwiki/crystal_radio/detector**. However, long before the sensitivity of the diode becomes the limiting factor, four other factors will limit the performance of the radio you propose. Those are:

Selectivity — only one tuned circuit is used and it is not impedance matched at input or output.

Antenna length — definitely use more than 10 feet — a goal would be 50 feet and as high as possible.

Ground losses — connect a wire to earth or to a large expanse of metal.

Frequency of operation *(also related to selectivity)* — with this type of circuit, as you increase frequency, the bandwidth increases. This means it lets through more and more stations at the same time.

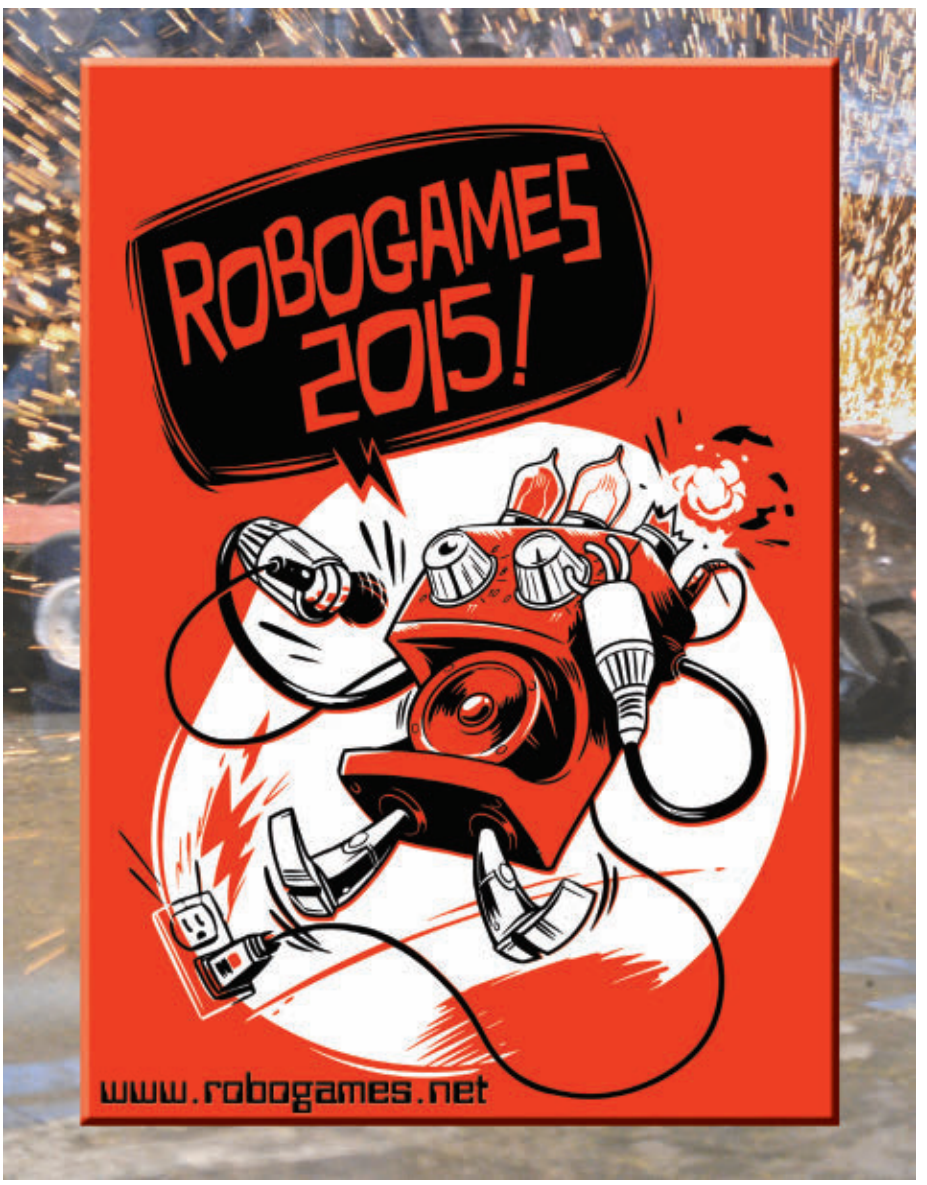
If you haven't had the opportunity to read them, you'll probably find the insights in the Wiki entry on crystal radios time saving. Especially note the sections on tuned circuits, impedance matching, and the problem of selectivity. It can be found at **http://en.wikipedia.org/wiki/Crystal_radio**. The following URL shows how to connect your tuning circuit and diode directly to your LM386 without the LM741 you have in the middle of the circuit: **http://makerf.com/posts/an_lm386_powered_crystal_radio_in_an_altoids_smalls_tin**.

You specified a number of turns for your coil but I didn't see any diameter for it. Starting coil designs would be 56 turns for a five inch diameter oatmeal box or 75 turns on a 2-1/8 inch diameter coil — each of which could be used with your 365 pf variable capacitor; 22 to 24 AWG bare enameled wire would work for the 5" diameter; 28 to 30 AWG would work for the 2-1/8" diameter.

To help optimize selectivity, you want what's called a "square coil." This means the coil length is about equal to the diameter. Not critical, but helpful. Small diameter wire increases resistance which degrades selectivity. It's likely to be less frustrating to first get your design working at the lower AM broadcast band frequencies before pushing up into the shortwave frequencies.

Last, it looks like you might put taps on your coil. The following URL has photos that might give you helpful ideas: **www.midnightscience.com/downloadfiles/XSOB1-manual-050108.pdf**. Once on the website, click on the "Oatmeal box crystal set." Please accept my apologies if I've included too much information. Best wishes for your success.

David Tancig
Columbia, SC



READER FEEDBACK

Continued from page 45

programming my PICAXE projects for several years now, and I've never had a problem that was caused by the USB power supply. (I do include a bypass capacitor on each of the two sets of breadboard power rails.) Based on the results I saw on the scope, I think a 5V USB wall wart would also function effectively as a breadboard power supply.

Even so, I appreciate your drawing attention to this issue. If I see any USB power-related problems in the future, I'll report them in the Primer. Thanks!

Ron Hackett

Notice to Smiley's Workshop column fans:

Unfortunately, Joe Pardue will not be able to continue his popular series at this time. However, we do hope to have his column back in as soon as it is possible for him to return.

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AMATEUR RADIO AND TV
Alpha Node Hub 66
National RF 20
Ramsey Electronics 82-83

ANTENNA
Alpha Node Hub 66

BATTERIES/CHARGERS
Cunard Associates 20

BUYING ELECTRONIC SURPLUS
All Electronics Corp. 9
Earth Computer Technologies 6
Weirdstuff Warehouse 20

CCD CAMERAS/VIDEO
Ramsey Electronics 82-83

CIRCUIT BOARDS
Accutrace Inc.. 17
AP Circuits 44
Cunard Associates 20
Dimension Engineering 62
ExpressPCB 29
Front Panel Express LLC 77
PCB Pool 28
Saelig Co. Inc. .....Back Cover

COMPONENTS
All Electronics Corp. 9
Anaren 5
Electronix Express 34
LF Components.....71

COMPUTER
Hardware
Earth Computer Technologies 6
Weirdstuff Warehouse 20

Microcontrollers / I/O Boards
Custom Computer Services 75
Images Co. 28
M.E. Labs 35
MikroElektronika 3
Technologic Systems 15

DATA ACQUISITION
Measurement Computing.....63

DESIGN/ENGINEERING/ REPAIR SERVICES
Accutrace Inc.. 17
Cleveland Institute of Electronics.66
ExpressPCB 29
Front Panel Express LLC 77
Images Co. 28
National RF 20
PCB Pool 28

DIGITAL OSCILLOSCOPES
Rigol Technologies 16

EDUCATION
Boxed Kit Amps 20
Cleveland Institute of Electronics.66
Command Productions 7
LF Components.....71
NKC Electronics 20
Poscope 29

EMBEDDED TOOLS
NetBurner 2

ENCLOSURES
Front Panel Express LLC 77

ETHERNET
Custom Computer Services 75

EVENTS
Maker Faire 21
RoboGames 80
Trenton Computer Show 45

HI-FI AUDIO
Boxed Kit Amps 20

KITS & PLANS
Boxed Kit Amps 20
Custom Computer Services 75
Earth Computer Technologies 6
LF Components.....71
NetBurner 2
NKC Electronics 20
Ramsey Electronics 82-83

MISC./SURPLUS
All Electronics Corp. 9
Front Panel Express LLC 77
Weirdstuff Warehouse 20

PCB ASSEMBLY
Accutrace Inc.. 17

PROGRAMMERS
M.E. Labs 35
MikroElektronika 3

RF TRANSMITTERS/ RECEIVERS
Anaren 5
National RF 20

ROBOTICS
Cleveland Institute of Electronics.66
Robot Power 20

SATELLITE
Team Synergy Moon 79

SENSORS
CH Robotics 17

TEST EQUIPMENT
Dimension Engineering 62
Images Co. 28
Measurement Computing.....63
NKC Electronics 20
Poscope 29
Rigol Technologies 16
Saelig Co. Inc. .....Back Cover

TOOLS
MikroElektronika 3
NetBurner 2
PanaVise 17
Poscope 29

WAVEFORM GENERATORS
Rigol Technologies 16

WIRELESS PRODUCTS
Anaren 5
Measurement Computing.....63

Accutrace Inc.. 17
All Electronics Corp. 9
Alpha Node Hub 66
Anaren 5
AP Circuits 44
Boxed Kit Amps 20
CH Robotics 17
Cleveland Institute of Electronics 66
Command Productions 7
Cunard Associates 20
Custom Computer Services 75
Dimension Engineering 62
Earth Computer Technologies ...6
Electronix Express 34
ExpressPCB 29
Front Panel Express LLC 77
Images Co. 28
LF Components.....71
Maker Faire 21
M.E. Labs 35
Measurement Computing 63
MikroElektronika 3
National RF 20
NetBurner 2
NKC Electronics 20
PanaVise 17
PCB Pool 28
Poscope.....29
Ramsey Electronics 82-83
Rigol Technologies 16
RoboGames 80
Robot Power 20
Saelig Co. Inc. .....Back Cover
Team Synergy Moon 79
Technologic Systems 15
Trenton Computer Show 45
Weirdstuff Warehouse 20

IT'S SPRINGTIME AT RAMSEY!

Super-Pro FM Stereo Radio Station

SPRING SALE!

- ✔ **PLL synthesized for drift-free operation**
- ✔ **Built-in mixer - 2 line inputs and one microphone input, line level monitor output!**
- ✔ **Frequency range 88.0 to 108.0, 100 kHz steps**
- ✔ **Precision active low-pass "brick wall" audio filter!**
- ✔ **Dual LED bar graph audio level meters!**
- ✔ **Automatic adjustable microphone ducking!**
- ✔ **Easy to build through-hole design!**

The true professional workhorse of our FM Stereo transmitter line, the FM100B has become the transmitter of choice for both amateurs and professionals around the world. From the serious hobbyist to churches, drive-in theaters, colleges and schools, it continues to be the leader. Not just a transmitter, the FM100B is a fully functional radio station and provides everything but the audio input and antenna system! Just add that and you're on the air!

This professional synthesized transmitter is adjustable directly from the front panel with a large LED digital readout of the operating frequency. Just enter the setup mode and set your frequency. Once selected and locked you are assured of a rock stable carrier with zero drift. The power output is continuously adjustable throughout the power range of the model selected. In addition, a new layer of anti-static protection for the final RF amplifier stage and audio inputs has been added to protect you from sudden static and power surges.

Audio quality is equally impressive. A precision active low-pass brick wall audio filter and peak level limiters give your signal maximum "punch" while preventing overmodulation. Two sets of rear panel stereo line level inputs are provided with front panel level control for both. Standard unbalanced "RCA" line inputs are used to make it simple to connect to the audio output of your computer, MP3 player, DVD player, cassette deck or any other consumer audio source. Get even more creative and use our K8094 below for digital storage and playback of short announcements and ID's! In addition to the line level inputs, there is a separate front panel microphone input.

All three inputs have independent level controls eliminating the need for a separate audio mixer! Just pot-up the source control when ready, and cross fade to the 2nd line input or mic! It's that simple! In addition to the dual stereo line inputs, a stereo monitor output is provided. This is perfect to drive studio monitors or local in-house PA systems. The FM100B series includes an attractive metal case, whip antenna and built in 110/220VAC power supply. A BNC connector is also provided for an external antenna. Check out our Tru-Match FM antenna kit, for the perfect mate to the FM100B transmitter. We also offer a high power kit as well as an export-only assembled version that provides a variable RF output power up to 1 watt. The 1 watt unit must utilize an external antenna properly matched to the operating frequency to maintain a proper VSWR to protect the transmitter.

(Note: The FM100B and FM100BEX are do-it-yourself learning kits that you assemble. The end user is responsible for complying with all FCC rules & regulations within the US or any regulations of their respective governing body. The FM100BWT is for export use and can only be shipped to locations outside the continental US, valid APO/FPO addresses or valid customs brokers for documented end delivery outside the continental US.)

FM100B Super-Pro FM Stereo Radio Station Kit, 5uW to 25mW Output — SPRING SALE! ~~*$239.95*~~
FM100BEX Super-Pro FM Stereo Radio Station Kit, 5uW to 1W Output — SPRING SALE! ~~*$299.95*~~

Four-Mode Keyless Entry Test Set

Just like the days of "plugs, points, and condenser" are over, so are the days of having the hardware store grind out a spare key for your car!

Now when your keyless access system doesn't work, you need to accurately detect what part of the system is malfunctioning. This could be anything from a dead battery in the key fob, a "brain-dead" key fob, to malfunctioning sensors, antennas, or other system components in the vehicle. Until now there was no way to determine where the system was failing.

Testing your system is easy. To test the complete 125 kHz/315 MHz communications path just stand close to the vehicle with the WCT3 and your key fob in hand. Press the test button and the WCT3 will detect and display the presence of the vehicle's 125kHz/20KHz signal and, if they "handshake", will also detect and display the presence of your key fob's 315MHz return signal. You can independently test key fob only signals (panic, lock, trunk, etc.) by holding the key fob near the WCT3, pressing the test button, and pushing the function button on the key fob.

The same functionality testing can be done with IR key fobs. The modulated IR signal is detected and will illuminate the IR test LED on the test set.

If you know a few "secrets" you can also see if the tire pressure sensors/transmitters are generating signals or the built-in garage door opener in your rear view mirror is transmitting a signal! Runs on a standard 9V battery. Also available factory assembled & tested.

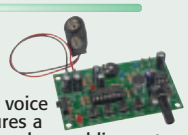
WCT3 Keyless Entry Test Set Kit **$59.95**

Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

IG7 Ion Generator Kit **$64.95**

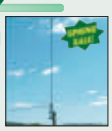
Digital Voice Changer



This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! Features a built-in microphone and both a speaker and line output. Runs on a standard 9V battery, not included.

MK171 Digital Voice Changer Kit **$14.95**

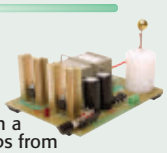
Collinear Vertical FM Antenna



Our 5/8 wave omni antenna has been the standard for LPFM insallations worldwide. Provides 3.4dB gain while keeping the signal radiation low to the horizon for maximum range. Field tuneable over the entire FM range for a perfect match. SO239 connector for PL259 plug.

FMA200E Omnidirectional FM Antenna ~~*$119.95*~~

HV Plasma Generator



Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.

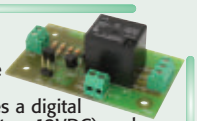
PG13 HV Plasma Generator Kit **$64.95**

Audio Recorder & Player

Record and playback up to 8 minutes of messages from this little board! Built-in condenser mic plus line input, line & speaker outputs. Adjustable sample rate for recording quality. 4-switch operation that can be remote controlled! Runs on 9-12VDC at 500mA.

K8094 Audio Recorder/Player Kit **$32.95**

Logic Interface Module



Interface your digital output to the real world with an on-board SPDT relay rated at 240V at 10A! It takes a digital low (.5VDC or less) or a high (+1 to +12VDC) and provides your choice of an active low or high closure! It's that simple! Runs on 12VDC at 60mA.

RI1 Logic Interface Kit **$17.95**

Signal Magnet Antenna

The impossible AM radio antenna that pulls in the stations and removes the noise, interference, and static crashes from your radio! Also helps that pesky HD AM Radio stay locked! Also available factory assembled.

SM100 Signal Magnet Antenna Kit **$89.95**

Passive Aircraft Monitor

PATENTED!

The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Receiver Kit **$89.95**

Tunable AM Radio Transmitter

The AM1 is a great first kit and a fine low power AM broadcaster for the hobbyist on a budget. It's a great way to learn the basics of AM broadcast technology, not to mention basic soldering and component identification (if you're a beginner!). The transmitter can be tuned to broadcast anywhere in the AM band (550 to 1600 kHz). Setting frequency is simple.

With 100 mW of output power, range can be up to ¼ mile. Connect any line level audio source from your CD player, tape deck, or mic mixer to the RCA input on the rear panel of the AM1C and you'll be on the air. It's that simple!

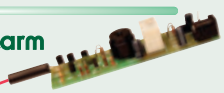
AM1C Tunable AM Radio Xmtr Kit **$34.95**

Broadband RF Preamp

Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Assmb.

PR2 Broadband RF Preamp **$69.95**

Laser Trip Sensor Alarm



True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit **$29.95**

Active Receive Antenna

The popular antenna for the serious DX'ers works on all bands - shortwave, HF, VHF, and UHF yet performs like a 60' long wire antenna! Provides over 15dB of gain, and includes auto-off RF bypass and front panel gain control.

AA7C Active Antenna Kit **$59.95**

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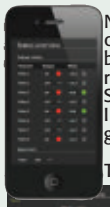
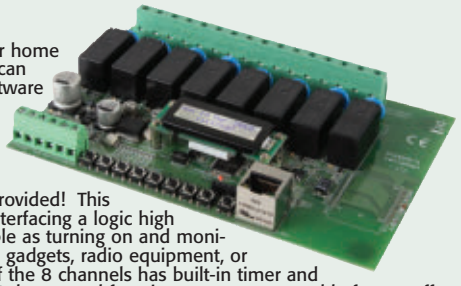
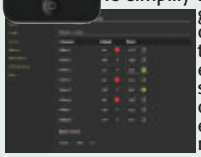
8-Channel Remote Ethernet Controller





Now you can easily control and monitor up to 8 separate circuits via the standard Ethernet network in your home or office. Connection wise it couldn't be simpler. The controller functions as an IP based web server, so it can be controlled by any internet browser that can reach your network! There are no drivers or proprietary software required, just access the controller like any web page from your PC, laptop, or even your smartphone! Security is assured allowing up to 4 separate user credentials. The controller can be set to a specific static IP within your network subnet or can be set to DHCP (auto negotiate). The controller can even be programmed to send you an email to notify and confirm power up and status changes!



To simplify the connection of your equipment to the controller, 8 separate and isolated relay outputs are provided! This gives you internet or network control of up to 8 separate functions. No need to worry about interfacing a logic high or logic low, or burning up the interface! The applications are endless! From something as simple as turning on and monitoring lights at your house with a normal latched closure to advanced control of your electronic gadgets, radio equipment, or even your garage door! Each relay contact is rated at 12A at 30VDC or 16A at 230VAC. Each of the 8 channels has built-in timer and scheduler programs for day, weekend, working days, every day, and every day except Sunday. Relay control functions are programmable for on, off, or pulse (1-99 seconds, 1-99 minutes, or 1-99 hours). In addition to control functions, the web interface also displays and confirms the status of each channel. Each channel can be custom labeled to your specific function name. The controller operates on 12VDC or 12VAC at 500mA or our new AC121 global 12VDC switching power supply below. Factory assembled, tested, and ready to go! Even includes a Cat-5 cable!

VM201 **8-Channel Remote Ethernet Controller, Factory Assembled & Tested** **$169.95**

Laser Beam Audio Communicator

Now you can talk to your friends over one of the most secure long-distance transmission types available, a laser beam! The transmitter uses a microphone or external audio to modulate a laser beam on and off at a rate of more than 16kHz so the audio fidelity is much better than that of a standard 3kHz telephone line!

The receiver includes filtering to remove the 16kHz carrier and leave behind the high quality audio, and then boost its level for use with earphones. Transmitter audio AGC keeps your level perfect! Includes transmitter, receiver and laser pointer. Each runs on a 9V battery (not included).

LBC6K **Laser Beam Audio Communicator Kit** **$59.95**

Precision PC Plane Antennas

Our LPY series PC antennas continue to be the favorite for virtually all RF and wireless applications. From microwave links, wireless mics, to RFID, we've got you covered. Check our site for details!

LPYSeries **Precision PC Plane Antennas** **from $29.95**

Stereo Ear Super Audio Amp

This "Stereo Ear" amp is one of the neatest and handiest high gain amps you will find! Dual high sensitivity electret mics are amplified 50x to provide the ultimate stereo source! Output is 3.5mm jack, runs on 3ea AAA's.

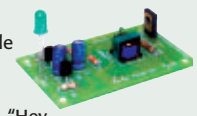
MK136 **Stereo Ear Audio Amplifier Kit** **$9.95**

Tone Encoder/Decoder

Encode and decode with the same kit! This little mini-kit will simultaneously encode and/or decode any audio frequency between 40Hz and 5,000 Hz! Precision 20-turn trim pot adjustment! 5-12VDC.

TD1 **Tone Encoder/Decoder Kit** **$9.95**

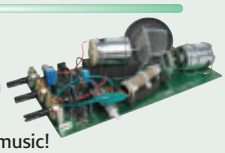
Tickle-Stick Shocker



The kit has a pulsing 80 volt tickle output and a mischievous blinking LED. And who can resist a blinking light and an unlabeled switch! Great fun for your desk, "Hey, I told you not to touch!" Runs on 3-6 VDC.

TS4 **Tickle Stick Kit** **$9.95**

Laser Light Show



Just like the big concerts, you can impress your friends with your own laser light show! Audio input modulates the laser display to your favorite music! Adjustable pattern & speed. Runs on 6-12VDC.

LLS1 **Laser Light Show Kit** **$49.95**

Optically Isolated Module

The hobbyist's headache solver! Converts any AC or DC signal to logic level. The beauty is that the input and output are totally isolated from each other! Output can drive up to 150mA at 40VDC.

OM2 **Optically Isolated Module Kit** **$16.95**

RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

SA7 **RF Preamplifier Kit** **$16.95**

12VDC Regulated Switching Supply

Go green with our new 12VDC 1A regulated supply. Worldwide input 100-240VAC with a Level-V efficiency! It gets even better, includes DUAL ferrite cores for RF and EMI suppression. All this at a 10 buck old wallwart price! What a deal!

AC121 **12VDC 1A Regulated Supply** **$9.95**

Classic Nixie Tube Clocks

HOT SELLER!

Our next generation of classic Nixie tube clocks perfectly mesh today's technology with the Nixie era technology of the 60's. Of course, features you'd expect with a typical clock are all supported with the Nixie clock... and a whole lot more!

The clocks are programmable for 12 or 24 hour mode, various AM/PM indications, programmable leading zero blanking, and include a programmable alarm with snooze as well as date display, 4 or 6 tube, kit or assembled!

We then jumped the technological time line of the 60's Nixie displays by adding the latest multi-colored LEDs to the base of the Nixie tubes to provide hundreds of illumination colors to highlight the glass tubes! The LED lighting can be programmed to any color and brightness combination of the colors red, green, or blue to suit your mood or environment.

Then we leaped over the technological time line by integrating an optional GPS time base reference for the ultimate in clock accuracy! The small optional GPS receiver module is factory assembled and tested, and plugs directly into the back of the clock to give your Nixie clock accuracy you could only dream of!

The clocks are available in our signature hand rubbed Teak & Maple, or futuristic clear acrylic bases. You also have your choice of IN-14 or highly sought after IN-8-2 nixie tubes (for the 6-tube clock).

NIXIE **Classic Nixie Tube Clock Kits** **From $229.95**

Touch Switch

The ultimate touch switch! Touch once - it's on, touch again - it's off, or use the momentary outputs that stay on only as long as touched. Two switch circuits on each board. Drives loads up to 100mA. Runs on 6-12VDC.

TS1 **Touch Switch Kit** **$9.95**

12VDC Worldwide Supply

It gets even better than our AC121 above! Now, take the regulated Level-V green supply, bump the current up to 1.25A, and include multiple blades for global country compatibility! Dual ferrite cores!

PS29 **12VDC 1.25A Global Power Supply** **$19.95**

Tri-Field Meter Kit

THE GHOST DETECTOR!

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

TFM3C **Tri-Field Meter Kit** **$74.95**

Electronic Watch Dog

A barking dog on a PC board! And you don't have to feed it! Generates 2 different selectable barking dog sounds. Plus a built-in mic senses noise and can be set to bark when it hears it! Adjustable sensitivity! Unlike my Greyhound, eats 2-8VAC or 9-12VDC, not fussy!

K2655 **Electronic Watch Dog Kit** **$39.95**

Telescopic Whip Antenna

Ideal for handheld portables, receivers, and communications test equipment. Professional chrome finish with integral swivel mounted BNC connector matches virtually any application whether top mounted or 90 degree rear panel mounted. Whip extends 5.25" to 27.75" to cover a wide variety of frequencies.

WA10 **Telescopic Whip Antenna, BNC** **$14.95**

Sniff-It RF Detector Probe

Measure RF with your standard DMM or VOM! This extremely sensitive RF detector probe connects to any voltmeter and allows you to measure RF from 100kHz to over 1GHz! So sensitive it can be used as a RF field strength meter!

RF1 **Sniff-It RF Detector Probe Kit** **$27.95**

GET THE NUTS AND VOLTS DISCOUNT!

Mention or enter the coupon code ***NVRMZ142*** *and receive 10% off your order!*

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Prices, availability, and specifications are subject to change. Not responsible for typos, mistakes, stupids, or confusion that Spring is even approaching! Robin gave me an extra week to dig out of "Storm Juno" and prepare this Spring ad! How ironic is that! Visit www.ramseykits.com for the latest pricing, specials, terms and conditions. Copyright 2015 Ramsey Electronics®.. so there!

WHAT'S HOT

Test & Measurement and Other Essentials!

OSCILLOSCOPES

Rigol

RIGOL's test & measurement instruments compete with industry leaders – but more affordably: Analog & Mixed-signal Scopes to 1GHz with AWG, Function/AWGs from 20MHz-350MHz RF Signal Gens to 6GHz, Pwr Supplies, DMMs, & Spectrum Analyzers.

Owon

OWON's affordable, reliable, easy-to-use precision benchtop & handheld scopes are unbeatable in their price range. Battery powered and portable options for field use. Owon's Triple Output Power Supplies offer remote control & preset configurations.

Pico

PICO TECHNOLOGY - the world's best PC-based oscilloscopes & data acquisition equipment with the performance of good bench scopes; compact & lightweight - ideal for field work. Award-winning automotive scopes find engine & electric faults quickly.

MISC.

USB Control

Need to interface a PC USB port to other equipment? We have modules for USB-I2C with additional I/O, USB data acquisition, USB-serial (some within the connector itself!), the best and most reliable USB-serial cables, and USB isolators to eliminate ground loops.

Power Supplies

We stock numerous power supplies from simple "wall-warts" for low-voltage/ low-current needs, to more complex bench-top supplies with single or multiple outputs, programmable supplies, flexible output current/voltage supplies with multiple communication options.

3D Printers

3D printing makes product and device development faster and cheaper – rapidly build concept parts and projects. We have the latest 3D printers from industry leaders MakerBot and Afinia, as well as the best 3D printing filament available for creating high quality parts quickly!

CIRCUIT/PCB TEST

ABI Electronics

ABI ELECTRONICS - PCB test/repair: **BoardMaster 8000:** easy-use PCB test system; **JTAGMaster:** programs/tests via JTAG port; **RevEng Schematic Learning System:** generates schematics from PCBs; **SENTRY:** detects counterfeit components.

MQP

MQP ELECTRONICS – USB2.0 Analyzers /Gens, Protocol/Electrical Test equipment, offering unbeatable value/performance ratio and Vbus monitoring. GraphicUSB software offers full analysis of std USB2.0 protocol with Class Analysis options.

Cosview

COSVIEW - range of extremely affordable USB-connected inspection microscopes & stands, very useful for examining printed circuit boards and small integrated circuits for production faults or part number markings. Polarizing filter option which excludes surface glare is available.

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